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Spatial and Temporal Trends in the American Lobster, *Homarus americanus*, Fishery in the Bay of Fundy (Lobster Fishing Areas 35, 36, and 38)

Tendances spatiales et temporelles de la pêche du homard, *Homarus americanus*, dans la baie de Fundy (zones de pêche du homard 35, 36 et 38)

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Abstract

Temporal trends in landings for Lobster Fishing Areas (LFAs) 35, 36, and 38 are reviewed, as are key fisheries sampling programs conducted from 4 principal fishing ports since 1977. Landings were stable between 1986/87 and 1993/94 (range 942 – 1046 t), then increased to 2566 t by 1998/99. Changes in participation level (particularly in LFAs 35 and 36) and exploration of new fishing grounds account for some of this increase. There are indications of a major recruitment pulse in the lobster population during the 1990's. Recent fishery-dependent recruitment signals in the upper Bay of Fundy fishery in LFA 35 are lower than those seen in the mid-1990's. Available pre-recruit indices are reviewed, as are uncertainties in extending conclusions on lower recruitment levels from a restricted set of survey locations to the fishery in general.

The spatial distribution of the lobster fishery was modeled for the 1998/99 and 1999/2000 fishing seasons using an assumption-based allocation of landings in relation to a 10-min grid system, and expansion of landings to catch at size, using an expanded at-sea sampling program. For the 1999/2000 fishing season in LFAs 35-38 (which had the highest sampling frequency), 63 - 68% of lobsters estimated to have been landed were in the first molt group (81-94 mm CL). LFA 35-38 catches contain greater percentages of lobsters in larger molt groups (7 – 14% 110+ mm CL) than the catch in the adjacent LFA 34 fishery (4% 110+ mm CL).

Estimates of exploitation rates and assessment modelling using the egg per recruit approach presented in the last assessment were not updated due to the uncertainty in recruitment trends.

Résumé

Nous passons en revue les tendances temporelles des débarquements de homard dans les zones de pêche de pêche du homard (ZPH) 35, 36 et 38, ainsi que les principaux programmes d'échantillonnage des prises menés depuis quatre grands ports de pêche depuis 1977. Les débarquements étaient stables de 1986-1987 à 1993-1994 (variant entre 942 t et 1 046 t), puis ont grimpé à 2 566 t dès 1998-1999. Les changements dans le niveau de participation (en particulier dans les ZPH 35 et 36) et l'exploration de nouvelles pêcheries expliquent en partie cette augmentation. Certains signes portent à croire à une forte poussée de recrutement dans les années 1990, tandis que les indicateurs récents du recrutement issus de la pêche dans la ZPH 35, située dans l'arrière-baie de Fundy, sont plus faibles que ceux observés au milieu des années 1990. Nous passons en revue les indices disponibles sur les prérecrues, ainsi que les incertitudes quant à l'application à la pêche en général des conclusions sur les niveaux de recrutement plus faibles issues d'un nombre limité de lieux de relevé.

Nous avons établi un modèle de la distribution spatiale des lieux de pêche du homard pendant les saisons de pêche 1998-1999 et 1999-2000 en répartissant, d'après des hypothèses, les débarquements sur un système de quadrillage à maille de 10 minutes et en transformant, d'après les résultats d'un programme élargi d'échantillonnage en mer, les débarquements en prises selon la longueur. Pour la saison de pêche 1999-2000 dans les ZPH 35 à 38 (où la fréquence d'échantillonnage était la plus élevée), de 63 à 68 % des homards considérés comme débarqués appartenaient au groupe de la première mue (LC : 81-94 mm). Les prises issues de ces ZPH comptent un pourcentage plus élevé de homards des groupes de mue plus longs (de 7 à 14 % d'individus dont la LC mesure 110 mm et plus) que les prises récoltées dans la ZPH 34 adjacente (4 % d'individus dont la LC mesure 110 mm et plus).

Nous n'avons pas mis à jour les estimations des taux d'exploitation et le modèle d'évaluation reposant sur l'approche du nombre d'oeufs par recrue présentés dans la dernière évaluation en raison de l'incertitude entourant les tendances du recrutement.

Introduction

The Fishery

In the Bay of Fundy, Canada, the American lobster (*Homarus americanus*) is a valuable resource (1999 landed value $37.4 million) shared by lobster fishers from three fishery management units referred to as Lobster Fishing Areas or LFA' s (Table 1; Fig. 1). Lobster fishing began in the Bay of Fundy in the mid-1800's, and landings data exist from the 1890's (Williamson, 1992).

The fishery is managed by input controls including limited entry, minimum size (carapace length, CL, mm), prohibition on landing egg-bearing females, and trap limits. There are a total of 339 Category A Vessel Based licenses, 33 Partnership licenses and 3 Category B (part time) licenses in the three LFA's. The number of participants and trap limits vary among LFA's (Table 1A). With the present fishing season structure, which includes winter fishing off Grand Manan, lobsters are accessible to trap fisheries in various portions of the Bay of Fundy from Oct 15 to July 31 (Table 1B). Increases to the minimum size, and new conservation approaches involving voluntary v-notching activity, and a prohibition on landing v-notched lobster, have recently been introduced (Table 1C).

The status of lobster stocks in LFA's 35, 36, and 38 was last assessed in 1998 by Lawton et al (1999). The adjacent LFA 34 fishery was also assessed at that time (Pezzack et al 1999). Reference is made to these earlier reports for background information on historical aspects of the fisheries, earlier biological studies, and assessment methodologies where these have not changed substantially since the last assessment. This document updates stock status of LFA's 35, 36, and 38 at the end of the 1999/2000 season. Recent data from biological sampling during the Fall 2000 fishery has been included where this helps in interpreting trends; however, no comprehensive analysis is presented on the 2000/01 fishing season.

Recent Management Issues

A major conservation management program was initiated in Atlantic Canada in light of the October 1995 review of the Atlantic lobster fishery by the Fisheries Resource Conservation Council (FRCC, 1995). The FRCC concluded that under the current management regimes, lobster fishers generally were "taking too much, and leaving too little". Based on available scientific data the FRCC concluded that Atlantic lobster fisheries are designed towards high exploitation rates, harvest primarily immature animals, and result in very low levels of egg production per recruit (estimated to be as low as 1-2% of what might be expected in an unfished population). While they accepted that lobster stocks have traditionally been quite resilient, they concluded that the risk of recruitment failure is unacceptably high.

Inshore lobster fishers which prosecute "winter" fisheries (LFA's 33-38) developed responses to a directive issued by the Minister of Fisheries and Oceans in December 1997 to set in place new conservation management measures. These were to be designed to achieve a doubling in egg production per recruit over a four-year period. Egg per recruit analyses, and discussion of science and management issues and uncertainties related to this target, were provided by Lawton et al (1999) and Pezzack et al (1999). A summary of the conservation measures introduced to date and a review of the main aspects of the subsequent science-industry debate on merits of key conservation plan elements is provided in Appendix 1.

Recent developments in stock assessment methodology

During the late 1990's the scale of fishery sampling increased in the Gulf of Maine LFA's. This was initiated in response to recommendations in the last stock assessment, and the continued need for Science advice on lobster conservation in relation to DFO's 4-year plan to double e/r. Additionally, consequences of the Marshall decision have increased the requirement for a capability to effectively sample, collate, and analyse lobster catch composition at a range of spatial and temporal resolutions.

Commencing in 1997 all new at-sea fishery sampling has been fully georeferenced. Waypoints are logged on GPS receivers for as many traps as possible on each sampling trip and later uploaded for data entry into the newly-developed Crustacean Research Information System (CRIS). Conversion to geo-referenced databases has required adoption and integration of a new range of software for analysis and plotting. For projects requiring batch aggregations and default plots, the Acon/SQL approach has proven the most useful, especially with the added convenience for users of having new scripts deployed on a virtual data centre (intranet site). For other plotting needs Mapinfo software has proven an effective GIS tool with good SQL functionality.

Complete Oracle tables now exist for all historic sea samples, and standardization of measurement units and methods has been performed converting all records to carapace lengths in mm. Also, catch per unit of effort, CPUE, determinations by port and date have been calculated using calculated weights and stored in an analytical table.

Data extraction and analytical needs are handled largely by the use of a library of SQLPLUS and PLSQL scripts in five computing environments: 1) executed in SQLPLUS sessions by the users; 2) executed as SQL_reads within Acon scripts on desktop; 3) executed as SQL_reads within Acon scripts deployed on the intranet site; 4) executed within Mapinfo against Mapinfo tables imported from Oracle; and 5) within Mapinfo directly against Oracle tables using ODBC links. Data entry for sea samples and potentially other tables is now possible outside the DFO firewall using the internet and CRIS data entry forms.

The present report describes an initial approach to determining catch size distribution in the Bay of Fundy LFA's which has utilized many of the above approaches for data storage and access. An assumption-based approach was used to model the spatial distribution of the lobster fishery in the Bay of Fundy for the fishing seasons 1998/99 and 1999/00 in relation to a 10-min grid system. Fishery data for the adjacent LFA 34 fishery (and offshore LFA 41 fishery) is already available at this resolution from industry catch reporting (Pezzack et al 2001). This preliminary spatial analysis for the Bay of Fundy is acknowledged to be speculative, but is presented to generate debate on possible extensions of grid-based (or other area-based) catch and effort reporting systems to the Bay of Fundy fishery.

Assessment Methods

Biological inputs

At-sea sampling: At-sea sampling provides detailed information on lobster size-structure in commercial traps. For each trap haul made on a given day of sampling, the location, depth, and trap type are recorded. All lobsters retained in the trap are examined to determine size (carapace length, CL, in mm), sex, moult condition, and egg development stage for berried lobsters (criteria described by Robichaud and Campbell, 1991). Biologists are able to convert the numbers caught into estimates of the catch weight of legal-sized animals by use of length-weight relationships. An at-sea sampling program has been maintained in the Fall and Spring fisheries in LFA's 35, 36 and 38 since 1978. Emphasis was placed on maintaining an annual series at 4 representative ports (Fig. 3A) during periods when operating resources were restricted. As local fishery issues were

addressed (e.g. aquaculture development in Annapolis Basin; Lawton et al 1995) additional area-specific sampling has been undertaken.

Sampling effort between 1981 and 1988 was between 20 and 62 samples annually (in total) across Lobster Fishing Areas (LFA's) 35, 36, and 38 (Fig. 1). Sampling rates dropped during the period 1989 to 1996 to between 8 to 21 samples annually as a result of budget constraints. Sampling increased in 1996 and 1997 to approach sampling rates achieved in the 1980's (24 and 30 samples, respectively), and more than doubled in 1998 and 1999 (to 71 and 80 samples, respectively).

In-season fisher-supplied catch data: In 1996, lobster fishers from LFA 35 raised concerns that, due to reduction in DFO Science sampling activity, Industry had insufficient information on contemporary catch size structure on which to select conservation measures. Subsequent discussions identified the basic elements for an Industry catch size monitoring program: voluntary participation, efficient data recording approach, commitment to timely feedback on results, and eventual incorporation of data into the stock assessment process. Specific data to be obtained was the number of traps being sampled, soak time, lobster size, sex and reproductive condition (occurrence of berried lobsters), total trap hauls and pounds landed on the sampling day, general location and depth range. A column for observations on v-notch lobster abundance was included because two adjacent lobster fishing areas planned to implement a v-notch conservation program.

Participating fishers (3 in 1997; 6 in 1998; 5 in 1999; 2 in 2000) monitored the size structure of their catch at-sea using custom-made calipers. Key to the incorporation of this scientific catch monitoring into the fisher's regular fishing activity was the development of a size gauge and logbook that would permit rapid measurement of lobsters. Whereas scientists use calipers to record individual lobster size to the nearest mm, a decision was made to adopt interval-based size-class measurement. The size interval system selected allowed Science to report back information to Industry in terms of lobster moult groups (Table 2).

Diving and trap-based research surveys: The 1998 stock assessment referenced some fishery-independent research projects which provide information on lobster population characteristics and recruitment trends (Lawton et al 1999). For the current assessment, this treatment has been expanded but is reported separately (Lawton et al 2001) due to the exploratory nature of the analysis. Studies include diving-based censuses of inshore lobster abundance at several sites in the Fundy Isles region of the Bay of Fundy, and a closed season trapping survey on Grand Manan (LFA 38).

Landings and Effort Analyses

Lobster landings data is accessed from Oracle database tables created by DFO's Marine Fisheries Division from data compiled by DFO Statistics Branch into the ZIF (Zonal Interchange Format) database. The ZIF database includes lobster landings by Statistical District, (STD), port and date in a series of tables aggregated by year since 1989 (called Identified_catches_YYYY). In order to analyze seasonal trends in the lobster fishery a separate Oracle table (Lobland) has been created which combines data for all years since 1989 for LFA's 34, 35, 36, and 38, incorporating STD's 24 to 81 (Fig. 2). There was a change in the mandatory catch reporting system in November 1995 from a system based on dealer sales slips to one based on individual fishers sending in monthly catch settlement reports. For the Bay of Fundy LFA's, the current catch settlement report only provides information on catch by port and date of landing.

Catch Size Distribution Analyses

In November 1998, as part of their lobster conservation plan, LFA 34 fishers adopted an expanded catch settlement reporting system, which required them to provide information on daily catch and effort by reference to a 10 min x 10 min grid system. The grid reporting system was designed to be extended to the Bay of Fundy LFA's (Fig. 4), but has not been adopted to date. An initial catch size distribution analysis was undertaken using an assumption-based approach to modeling the spatial distribution of landings in the Bay of Fundy for the 1998/99 and 1999/2000 fishing seasons. The following data organization was undertaken:

1. Based on historical fishery at-sea sampling, and at-sea samples for the period of this analysis, 10 min grids were defined into groups which showed consistency in sample size distributions. Ten groups (1-10) contained grids that were to be allocated landings (Fig. 4). A summary of available at-sea samples on a monthly basis for each group was then prepared (Appendix 2).

2. A table was created allocating monthly STD landings from October 1998 to July 2000 to 10 min grids using assumptions about the monthly distribution of the fishery in each STD (allocation provided in Appendix 3). These assumptions were made by stock assessment biologists from accumulated experience in sampling these fisheries and from prior interactions with Industry. As noted, the spatial allocation of landings is not meant to be definitive.

3. To combine outputs from the Bay of Fundy analysis with similar analyses for LFA's 34 and 41, the following fishing periods were defined:

Fishing Period	Calendar Months	Periods used in Bay of Fundy analysis
Fall	Oct, Nov, Dec	Oct, Nov, Dec (3 periods)
Winter	Jan, Feb, Mar	Jan to Mar combined (1 period)
Spring	April, May, June	April and May combined, June (2 periods)
Summer	July, August, Sep	July (1 period)

The fishing season is considered to start in October, with the opening of the LFA 35 fishery in inshore waters, and the offshore, LFA 41, "quota" year. Other inshore LFA's (34, 36, and 38) open in November. Not all fisheries are open each quarter, nor for all months in any given quarter.

4. For LFA's 35, 36, and 38 there were a total of 7 time periods in each fishing season for which separate landings expansions were prepared for each of the 10 groups of grids. When closed fishing periods were considered, there were a total of 108 group-time periods for the analysis of landings size composition over the two fishing seasons (see Appendix 4 for details).

5. During the two fishing seasons, a range of minimum sizes were in effect in the three LFA's as each moved from an initial minimum size of 81 mm CL to a final minimum size of 82.5 mm CL (Table 1C). In the database lobster size is entered in mm increments, so the following minimum sizes were used for catch estimation commencing with the indicated fishing seasons:

LFA	Fall 1998	Spring 1999	Fall 1999	Spring 2000
35	81	82	82	83
36	81	81	82	82
38	83	83	83	83

Calculation of number of lobsters landed at size: A series of SQL queries were built against Oracle tables of at-sea sample distributions. For a given group-time period:

1. Frequency distribution of lobsters was defined by 1mm increments for each sex for all of the lobsters sampled (including shorts and berried lobsters).

2. Numbers at size for each sex were converted to total sample weight at size using separate length-weight relationships for males and females.
3. Percent distribution of sample weight by 1mm increments was calculated for the legal portion of the sample.
4. Landings for the group-time period were allocated to the percent distribution of sample weight to generate landings by weight at size.
5. Number landed at size was determined by dividing landings weight by individual lobster weight.

In addition to yielding number of legal sized lobsters landed, the analysis also allowed the non-legal portion of the at-sea sample (shorts, and berried lobsters) to be scaled in proportion to the landings for the group-time period.

Mapping catch size distributions to grids: The analysis yielded catch at size at the resolution of groups of grids. To decompose the landings further to a grid basis the table on landings distribution by grid (Appendix 3) was reformulated to provide the percentage distribution of landings among component grids of each group. A final proportional allocation of the estimated numbers of lobsters at size was made to the individual grids within each group.

Fishing Mortality and Exploitation Rate

The 1996 Invertebrate Fisheries RAP recommended developing and using a common method of determining Fishing Mortality (F) rather than the 4 variations used in the 1996 stock assessments of lobsters across the Atlantic Region. The Length Cohort Analysis (LCA) was recommended as the common method of assessment because it uses all sizes and incorporates more information on growth and time at-size than the previously used length based methods, and has been routinely used in U.S. lobster fisheries assessments (Cadrin and Estrella 1996).

LCA was used in the 1998 Gulf of Maine inshore lobster stock assessments (Lawton et al. 1999; Pezzack et al. 1999) which provide references to the methodology. As noted in those documents the LCA method assumes constant recruitment. In the case of the Bay of Fundy fisheries there was evidence of a significant recruitment trend underway, particularly for the upper Bay of Fundy, and these prior LCA analyses were based on pre-1995 fishery conditions (Lawton et al. 1999).

E/R Analyses

Female lobsters have a complex reproductive pattern and non-continuous growth, factors that are not easily accommodated by traditional dynamic pool models (Beverton and Holt 1957). The egg per recruit analysis is based on the size-structured egg and yield per recruit model developed by Josef Idoine and Paul Rago (NMFS) and used in the 22nd Northeast Regional Stock Assessment Workshop (Anonymous 1996). The model is based on earlier work by Fogarty and Idoine (1988) and is described in detail in the 22nd SAW report and by Pezzack et al. (1999).

The e/r analyses conducted in the 1998 assessment of LFA 35-38 used two exploitation rate scenarios: 53% (based on LCA), and 70% (a high level, based on previous moult group comparison estimates; Lawton and Robichaud, 1992a). Incorporation of this high estimate of exploitation rate provided management and industry with an indication of the robustness of various management approaches. As a change in exploitation rate outside this relatively broad range would be required to generate substantially different estimates of the benefits of various conservation management tools on an e/r basis, no new runs of the model have been conducted in the current assessment.

Results and Discussion

Landings and Effort Analyses

Temporal trends by Lobster Fishing Area: Lobster landings in the Bay of Fundy were first reported in 1892, on an annual basis. Landings peaked in 1894 at 1415 tonnes (t), then subsequently declined, over a 40-year period, to a low of 198 t in 1938 (Fig. 5). From 1939 onwards, landings increased to a second peak of 897 t in 1953. Current annual landings in LFA's 35 and 38 represent historical highs, while 1999 landings in LFA 36 (at 842 t) are the highest this century, within 120 t of estimated peak landings of 962 t in 1896 (Fig. 5). The 1999 landings for the three LFA's combined (at 2624 t) is almost twice the first historical peak. More striking is that this also represents an approximate doubling from 1995 landings of 1372 t.

Pezzack et al (2001) compare long-term landings trends in the Canadian portion of the Gulf of Maine with other lobster fishing regions in Canada, and in the US lobster fisheries. Similar trends are apparent in the early part of the century with major declines in the late 1890's to mid-1920's followed by fluctuations through to the 1970's.

It is more appropriate to compare contemporary landings for the Bay of Fundy fisheries on a Fall - Spring season basis, particularly as much of the catch is represented by lobsters which have moulted into the first moult-group of the fishable stock during the previous summer. On a seasonal basis, for the Bay of Fundy as a whole, landings varied less than 2X (between 491-897 t) from 1946/47 to 1974/75 (Fig. 6). A post-war low of 296 t was reported in 1975/76; however landings rebounded to 545 t the following year, and began to increase gradually.

For the fishing seasons 1986-87 to 1993-94, total landings from the Bay of Fundy appeared to have stabilized at approximately 1000 t (range 942-1046 t; Fig. 6, Table 3). Landings then increased substantially to just over 2500 t in the 1998-99 season (a similar total is expected for 1999-2000 fishing season when landing information is complete). LFA 38 represented approximately 50% of the total landings during most of the period, but for the last three seasons the landings appear to be approximately equally distributed between the LFA's (Fig. 6).

Seasonal landings trends in the Bay of Fundy since the early 1980's appear to be lagged by approximately a decade from those observed in other fishing regions. During the 1980's a wide scale increase in lobster landings was observed over most of the range of lobsters in the western Atlantic. In a number of fishing regions landings doubled within 3-4 fishing seasons, and generally peaked in the 1990-1991 period (LFA 34 landings increased approximately 2.5X over that decade). Many regions have since declined, including the large Southern Gulf of St. Lawrence fishery, although landings in the LFA 34 fishery increased a further 30% since the mid-1990's (Pezzack et al 2001 provide a more detailed description of landings trends on a zonal basis). The recent rapid increase in landings in LFA's 35 and 36 since the 1994/95 season (Fig. 7) is reminiscent of events in these other fisheries, particularly LFA 34, during the 1980's.

Pezzack et al (2001) discuss potential causes of such widespread landings variation. They postulate that if abundance trends are related to large-scale environmental or ecological factors, then the reversal of landing trends already seen in other fishing regions may be of concern in the Gulf of Maine region where landings are still high overall. The approximate lag of a decade between the major increase in the outer Gulf of Maine (south-western Nova Scotia, mid-coast and southern Maine and Massachusetts) and recent trends in the Bay of Fundy and down-east Maine suggests more direct, perhaps cascading, recruitment-driven linkages. That is, the Bay of Fundy may now be benefiting from earlier recruitment events off southwestern Nova Scotia, which may have led to an enhanced larval subsidy. Clearly, further work needs to be done to evaluate how sub-areas within the Gulf of Maine may be linked oceanographically, and how recruitment trends may be synchronized across the region.

Temporal trends by Statistical District: Statistical Districts (and counties in Maine) are a convenient reporting unit as they combine one or more ports, and generally have sufficient numbers of fishers to avoid problems with releasing confidential information. An intermediate level of analysis is to group Statistical Districts (STD's) by general coastal areas of the Bay of Fundy and outer Gulf of Maine and examine increases in landings relative to a base year or fishing season. For Canadian STD's, landings are expressed relative to the 1983/84 fishing season. For Maine counties, annual landings provided by Carl Wilson, Lobster Biologist, Maine Department of Marine Resources, Boothbay Harbor, ME, are expressed relative to 1983 annual landings.

In the Upper Bay of Fundy, reported landings generally did not increase more than 2X between 1983/84 and 1993/94, except for STD 44 where landings rose to over 3X in the 1986/87 season, but then declined (Fig. 8). By 1993/94, landings for these upper Bay STD's were either close to or below 1983/84 levels in the Chignecto Bay and approaches, or between 1 and 3X 1983/84 landings in the Minas Basin and approaches (Fig. 8). Since then, landings in the principal STD's in the upper Bay (24, 41, 44, 79) have increased dramatically. In the Chignecto Bay area (STD's 24, 79) landings reached between 3 and 5X 1983/84 landings during the late 1990's. For the approaches to Minas Basin (STD's 41, and 44) landings rose to between 7 to 15X 1983/84 levels, but have recently shown a decline. For STD's 43 and 81 there have been no similar large increases. These STD's represent landings reported by only a few fishers.

Landings in the mid-Bay, from STD's 48 and 49 on the New Brunswick shore, and STD's 35 and 40 on the Nova Scotia shore (as well as Annapolis Basin, STD 39) show a very similar pattern to the upper Bay groups (Fig. 8). Landings increased by 2 to 3X over the decade from 1983/84, but then increased substantially in the late 1990's. As with the upper Bay, increases were most pronounced on the Nova Scotia shore, with landings increasing to between 6 and 14X the 1983/84 base season (as compared to 4 to 5X on the New Brunswick shore).

For the lower Bay of Fundy, landings for the principal STD's in LFA 36 (STD 51 and 53) have shown a progressive increase to between 3 and 5X 1983/84 landings by the late 1990's (Fig. 8). As with some STD's in upper Bay of Fundy, landings for STD 52 (Passamaquoddy Bay) represent landings from a few fishers, but still show an overall increase of 2X 1983/84 season landings. Landings from LFA 38 (STD, 50) show a gradual increase over the period of analysis, reaching 2X 1983/84 landings by the late 1990's (Fig. 8; see also Fig. 7).

On the Nova Scotia shore at the entrance to the Bay of Fundy there is a divergence in the landings trends in the late 1990's with STD's 36 and 38 showing a similar pattern to other Bay of Fundy STD's, and STD 37 remaining at between 2 and 3X 1983/84 landings.

Landings trends for the three northernmost Maine Counties (Knox, Hancock, and Washington Counties; Fig. 3) show a similarity to trends seen in the lower Bay of Fundy (Fundy Isles), having risen from 2X to 3X 1983 landings in the late 1990's (Fig. 8). For southern Maine Counties (York, Cumberland, Sagadahoc, and Lincoln) and southwestern Nova Scotia (STD's 32, 33, 34) landings were approximately 2X 1983/84 levels by the end of the 1990's, but do not show any substantial increase in the last three to four years (Fig. 8).

Landings data is influenced by many factors, such as reactivation of existing licenses (or purchase of licenses by new entrants), shifts in port of landing by specific boats, improved reporting of catches previously not reported on sales slips, mis-reporting of landings, or a combination of these factors. Nonetheless, there is a clear geographical pattern to recent landings trends, with STD's in the mid to upper Bay of Fundy, most particularly on the Nova Scotia shore, showing a divergence in landings trends from more southern areas. This pattern is consistent with the hypothesis presented earlier that there may have been an enhanced larval subsidy into the Bay of Fundy, but may also be due to improved conditions for larval and juvenile survival. Further analysis is required to separate out fishery-dependent effects from recruitment signals.

Vessel participation and effort analyses: Obviously one of the important factors in deciphering these landings trends is the level of participation by the fleet, both in terms of number of active licenses, landings per license, and effective fishing effort. As there is no fleet-wide reporting system for fishing effort (i.e. trap hauls), detailed effort analyses cannot be conducted over the long term. However, in the ZIF database landings data is recorded by distinct Canadian Fishing Vessel number (CFV) from 1989 onwards and allows some coarse-scale analysis of fleet participation and landings per boat. Reported landings were analyzed by fishing season quarters. For each LFA and quarter, the number of distinct CFV's which reported landings, and the landings per CFV were derived.

For LFA's 35 and 36 (Fig. 9 and 10) there was a pronounced shift in the number of distinct CFV's per quarter after the 1994/95 fishing season. This shift is evident in each quarter and may be linked with the change in catch reporting system from dealer sales slips to individual fisher catch settlement report, which came into effect in Fall 1995. For LFA 38 (Fig. 11) the number of distinct CFV's was high and relatively stable since 1989, especially in the Fall period (84 to 101 distinct CFV's per quarter as compared to 108 fulltime licenses). Although the change in reporting system may have a confounding effect, the increase in number of active CFV's in LFA's 35 and 36 is consistent with anecdotal information from lobster fishers on increased participation rates in the fleets subsequent to increases in landings being experienced starting in the mid-1990's.

For the Fall quarter, landings per CFV in LFA 35 (Fig. 9) have risen from between 1-2 t per CFV during the early part of the time series to 4-5 t per CFV in the late 1990's. Similarly, landings per CFV in LFA 36 (Fig. 10) have doubled over the time period. Landings per CFV in these LFA's are now similar to those reported from the LFA 38 fishery, where landings per CFV have been between 3 and 5 t over the whole time period (Fig. 11).

Similar increases in landings per CFV are seen in the Spring fishery in LFA's 35 and 36, representing an increase from approx. 1 to 3 t per CFV over the time series. For LFA 38 Spring landings have ranged between 2 to 3.5 t per CFV. Only LFA 35 is active in the Summer quarter, and landings in this period are from the month of July only. In recent years landings in July in LFA 35, at 2.5 t per CFV, have equaled the total catch per CFV taken in both Spring and Summer periods at the start of the time series.

During the Winter period (Jan, Feb, Mar), the only fishery open all months is LFA 38, as LFA 36 closes in mid-January. Only minimal landings of 0.2 and 0.6 t per CFV are reported for LFA 36 (Fig. 10), whereas 0.5 to 1.5 t per CFV are landed in the period in LFA 38 (Fig. 11). In LFA 38 landings in the Winter period show a rising trend over the time series.

Issues and uncertainty: Prior to 1998 we had no capability to easily interrogate data on Bay of Fundy lobster landings in order to analyze area- and time-specific trends. Preliminary exploration of the ZIF database has yielded some anomalous reports (e.g. outliers in landings per boat for certain ports; reduced catch reports) which need to be further investigated.

Changes in reporting systems in Fall 1995 may influence accuracy and completeness of landings data. Prior to 1996 landings were based on sales slips which may have missed a portion of the catch sold directly to consumers or sold directly in the USA. The size of the underestimation is not known, and may vary between LFA's. Post 1996 landings have been reported by fishermen directly and should be more complete. No analysis has been done to determine completeness or accuracy of reports. Thus increases observed since 1996 must be viewed in light of the change in reporting methods. However, the increases in overall landings and landings per CFV in the Bay of Fundy LFA's are coherent over various time and spatial scales, and no similar large-scale increases have been documented in other LFA's which undertook the same change in catch reporting system.

Landing levels are a function of abundance, level of fishing effort (trap hauls, SOD, timing of effort and fishing strategy), catchability (environmental, gear efficiency, density, and migrations) and

distribution of animals and effort. Changes in any of these can affect landings. Thus landings are not an exact reflection of abundance.

In fact great caution must be observed as increasing effective effort can maintain landings at a high level for a period of time while absolute abundance is declining. In the case of the Bay of Fundy fisheries though, and in particular LFA's 35 and 36, these trends in catch per CFV are supported by other fishery-dependent and fishery independent data which indicate that a significant recruitment event occurred during the 1990's (see also Lawton et al 2001).

Temporal Trends in catch size structure

At-sea sampling has been conducted since 1977 at four major ports in the Bay of Fundy. Samples are generally available from the first two weeks of the Fall season, and from the last two weeks of the Spring season. These periods represent the bulk of each fishing season catch (e.g. approx. 60% on Grand Manan). Robichaud and Campbell (1991) summarized the initial sea sampling program design, and reported on catch size composition up to the 1988/89 fishing season. We update this annual size composition data from the 1990/91 to 1999/2000 fishing season.

For Seal Cove (LFA 38), annual sampling has indicated a stable size frequency, with mean sizes in the sampled catch ranging from 77 - 85 mm CL (Fig. 12). In Fall sea samples few berried females have been noted in the traps (0.75 $\pm$ 0.24 (SE) berried females per 100 trap hauls over a 21 year period). Despite the move to include escape panels in lobster gear, pre-recruit lobsters are still retained in the traps in high numbers and recent observations in both the Fall and Spring fishery sampling show a continued strong representation of prerecruit lobsters.

Fishery samples from Dipper Harbour (LFA 36; Fig. 13) show a broader range of size classes of lobster, both in pre-recruit sizes, and larger lobsters beyond the first moult group (81-94mm CL). Berried females are represented in the time series (20 years) at a slightly higher level (3.73$\pm$0.7 berried lobsters per 100 trap hauls) than in Seal Cove. A progressive increase in pre-recruit presence in the sampled catch is indicated over the time series for samples taken in June. Prerecruit abundance has remained high over the last 4 years (Fig. 13).

Based on fishery sampling in the 1980's, Robichaud and Campbell (1991) characterized the size frequency of lobsters caught in various specific areas of the Bay of Fundy. They concluded that two fisheries (upper bay fishery in Chignecto Bay, Minas Basin and their approaches; deep-water fishery at the entrance to the Bay of Fundy) relied principally on intercepting seasonal migrations of larger, mature lobsters, rather than capitalizing on local annual production of new recruits.

In the time series presented in this assessment there is a marked shift in the at-sea sample distributions from Alma which may signal the appearance and passing of a major recruitment event. The mean size of lobsters sampled in Alma in the 1990/91 season was 93 and 100 mm CL in Fall and Spring samples, respectively (Fig. 14). The observed size structure was very similar to that reported by Robichaud and Campbell (1991) for samples taken from this port from 1978 to July1990. At the start of this time series biologists measured between 1.5 and 2 lobsters per trap haul. Since the 1990/91 fishing season there has been a downward shift in mean size of lobster sampled and an increase in the catch rate, both of pre-recruits and the first moult group (Fig. 14). Current at-sea samples in the Alma area may yield 10 lobsters per trap haul. The increase in pre-recruit abundance is seen most clearly in the Spring season samples where the catch size composition became similar to that seen in Seal Cove and Dipper Harbour by the mid 1990's.

For the last three years there has been an indication that catch rates of prerecruit lobsters are declining (Fig. 14; see also Fig. 16 for the Fall 2000 sample from Alma). In consultations with LFA 35 fishers, several factors have been highlighted which may complicate the interpretation of these

recent observations as being part of a general trend in the upper Bay fishery. These are considered below in the section "**fisher-supplied information on catch size structure**".

In contrast to sea sampling in Dipper Harbour and Seal Cove (which is conducted in November), fishery sampling in October in Alma intercepts berried female lobsters at a substantially higher rate (20.2±3.1 berried lobsters per 100 trap haul; 21 year series)

The final long-term time series, from North Head (LFA 38: Fig. 15), monitors a component of the fishing fleet which has some parallels to the midshore and offshore fleets in LFA's 34 and 41 (in terms of fishing strategies, soak days, winter fishing period, and lobster size distribution). The average size of lobsters has ranged from 114 to 128 mm CL in Fall sampling, and 121 to 130 mm CL in Spring sampling over the period 1990 to 2000 (Fig. 15). Catch rates of berried females in the Fall sampling period are comparable with those seen off Alma (24.9±3.9 berried lobsters per 100 trap haul; 19 year series).

Lawton et al (2001) provide a comparison of trap catch size distributions and diving censuses from research studies conducted during summer months off the port of North Head. In addition they compare survey data from 2000 with similar studies conducted in the late 1970's and early 1980's. These studies show a marked increase in the number of lobsters in the first and second moult groups, as well as the recent appearance of pre-recruit lobsters in these closed season sample areas. These observations are consistent with Industry reports on the recent appearance of pre-recruit lobsters during commercial fishing in deepwater areas off eastern Grand Manan.

A summary of the complete time series from these 4 ports (1977-2000) is provided in Figs. 17 and 18. Fig. 17 presents numerical catch rate of lobsters (male and female combined) by moult group; Fig. 18 presents the trends in catch rate in term of Kg of lobster per trap haul. For the Bay of Fundy there is no comprehensive logbook program in place which monitors fishing effort, and long-term trends in CPUE are available only from the at-sea monitoring program, and area-specific interview data. The new monitoring program in LFA 35 has provided some new information on catch rates, and as such programs expand could provide an important source of additional information. The available data shows either a stable CPUE (in terms of Kg per trap haul), or general increase over time (Fig. 18). Where index fisher logbook programs have been introduced (in other fishing areas) it is clear many factors influence in-season catch rates (e.g. temperature effects, non-linear relationship to abundance etc.).

Based on the occurrence of berried females in the at-sea sampling series from three ports over the period 1978 to 2000, a shift in the average size of berried females has occurred (Table 4, Fig. 19). Although sample sizes were 4 to 6 times greater for the period 1978-82 than for more recent time periods, the sample size range is comparable (Table 4). The median size has decreased by approximately 10 mm, and there are now higher percentages of berried female lobsters in the first two moult groups. There are persistent reports by lobster fishers of smaller berried female lobster in trap catches. For example, fishers in the commercial catch monitoring program in LFA 35 have recorded berried female lobsters below minimum legal size.

Fisher-supplied information on catch size structure: The trap-sampling program undertaken by Industry has been successful in providing data at time periods in the fishing season when sea sampling by Science was not practicable. Industry sampling from 1997 to 2000 was conducted in 3 areas in LFA 35. Between 1083 and 1216 trap hauls were sampled during the spring fishery from 1997 to 2000, with 1200 to 4060 lobsters measured. Fall sampling was only done during 1998 and 1999, when 215 to 367 trap hauls were sampled, and 829 to 2104 lobsters measured (Table 5).

Figure 20 shows correspondence between catch size structure as monitored by DFO Science observers and Fisher catch sampling during specific months from 1997 to 2000 (fishers also sampled catches at other periods in the fishing season). In Fall sampling in Minas Basin and off Advocate Harbour, both DFO and Industry sampling show decreases in the number of lobsters caught in prerecruit (75-80 mm CL) and first moult group (81-94 mm CL) size intervals between

1998 and 1999. However, the reduction in catch rate of 75-80 mm CL lobsters observed in DFO Science sampling in July in the Minas Basin from 1997 to 2000 is not reflected in the available Industry sampling (Fig. 20). Though not as pronounced, catch rates in the Advocate Harbour area are lower in July 2000 than in previous years in both DFO and Industry catch sampling.

Additional analyses were conducted to examine recent trends in the catch rates of prerecruit lobsters in DFO Science and Industry catch sampling in LFA 35 (Table 6). Through the 1990's DFO sampling in the Spring fishery was largely confined to the month of July. Industry contends that earlier onset of moulting activity in recent years may be responsible for the observed drop in prerecruit abundance in DFO sampling in 1999 and 2000, rather than a reduction in recruitment. DFO sampling was expanded to earlier months in the Spring season (May and June) in 1999 and 2000. Industry sampling also occurred during these months at several ports. There is variability in catch rates from May through July, but in a number of locations catch rates observed in July are either comparable to or higher than those seen in earlier months (Table 6). The highest catch rate of prerecruit lobsters observed in both DFO and Industry sampling conducted off Alma during the Spring fishery, 1998 -2000, is 1.17 lobsters/th, approximately half the catch rate seen between 1994-1997 (Fig 17). The maximum prerecruit catch rate in DFO Spring sampling off Alma, 1979 – 2000, was 2.59 lobsters/th in July 1997. Recent Industry and DFO sampling at other LFA 35 ports in the Spring is also encountering prerecruit lobsters up to a maximum of approximately 1/th (Table 6).

Catch rates of 75-80mm CL lobsters in DFO Fall fishery sampling from Alma peaked in Oct/Nov 1993 at 3.88 lobsters/th. Prerecruit catch rates have since dropped to approx. 0.8 lobsters/th by Fall 2000. Similar catch rates are observed in other DFO Fall sampling locations (Table 6). Catch rates observed by Industry sampling in Fall 1999 were lower than those in Fall 1998 (Table 6). DFO sampling takes place early in the Fall season and includes measurement of the total catch on a given day of fishing. Industry sampling is accumulated through monitoring a smaller number of hauls over a number of fishing days in each month. Industry sampling is difficult to accomplish when the fishery is experiencing high catch rates at the start of the Fall season or last few weeks of the Spring season.

In addition to changes in moult timing, Industry have contended that changes in fishing locations sampled by DFO off Alma (e.g. a movement to deeper waters away from juvenile habitats) may affect the interpretation of trends in pre-recruit abundance. New at-sea sampling protocols involve the documentation of trap sample location on a routine basis. Recent DFO samples from the Alma fishery involves a range of sampling locations, including shallow water areas.

However, DFO Fall sampling has typically involved a greater proportion of trapping locations > 15 ftm (Fig. 21). The number of trap hauls in water <15ftm has varied from 21 to 105 hauls from 1979-2000, while between 43 to 802 trap hauls were sampled in the >15 ftm category. Catch rates of 81-94 mm CL lobsters track the catch rates of 75-80 mm CL lobsters (Fig. 21A), with the highest catch rates being observed between 1993-1998.

DFO Spring sampling has generally included trapping locations in both depth categories. The number of trap hauls in water <15ftm has varied from 38 to 729 hauls, while between 91 to 1344 trap hauls were sampled in the >15 ftm category. Catch rates in both depth categories show a similar trend, with the highest catch rates of 75-80 mm CL lobsters occurring in the period 1994-1997 (Fig. 12b).

Issues and uncertainty: Industry sea sampling data from the upper Bay of Fundy confirms that the current catch rates of prerecruits 75-80 mm CL monitored by DFO off Alma in July are consistent with catch rates seen in other ports, and with recent sampling undertaken earlier in the Spring season. Unfortunately, the historical DFO sampling coverage at ports other than Alma is insufficient to indicate whether or not other ports have followed a similar trend (with maximum catch rates of prerecruits in the 1993-1997 period).

Long term fisheries monitoring data in the Bay of Fundy is limited in area coverage, but contains several time series which have identified important shifts in the size distribution of lobsters, particularly in the upper Bay. These trends indicate that a significant component of the observed increase in landings is related to increased recruitment. A series of detailed fisheries monitoring and biological research studies were conducted in the Bay of Fundy in the late 1970's/early 1980's, a level of program activity which could not be maintained throughout the later 1980's/early 1990's. Nonetheless, a number of additional surveys were conducted during this period, in particular diving and research trapping-based studies, which provide a baseline on population size distribution and abundance against which current fisheries information may be indexed. Lawton et al (2001) review diving and closed season trapping studies conducted in 2000 which were done in areas for which historical data exist, enabling comparisons of lobster abundance and population size structure.

Spatial Distribution of Catch by Moult Groups

One approach to displaying catch size composition is to map the spatial distribution of the number of lobsters caught per 10-min grid in relation to moult group categories (as determined by mean growth rates). **Moult group 1** represents lobsters that moulted into the catchable size in the summer prior to the fishing season of capture. **Moult group 2** represents lobsters that have survived one complete fishing season prior to capture in the current season. **Moult group 3 and Greater** contains a broad range of sizes of lobsters that have survived a number of fishing seasons prior to capture. The maximum size of lobster measured in the at-sea sampling program in the two fishing seasons was 202 mm CL, and 207 mm CL in 1998/99, and 1999/00 seasons, respectively. These lobsters were taken in the LFA 38 fishery. The maximum size of lobsters in the LFA 35 and 36 fisheries were 180 and 187 mm CL in the two seasons.

This mapping approach is consistent with that adopted for the LFA 34 and 41 fishery (Pezzack et al 2001). It permits a general comparison of the relative numbers of lobsters of different moult groups landed over the two fishing seasons in these diverse fisheries on a per unit area basis (Figures 22 and 23). In the case of the LFA 34 and 41 fisheries the fleet provides daily trap haul information in connection with landings per grid allowing the mapping of effort and catch per effort distributions. Pezzack et al (2001) use this detailed information to map out the fishing activity by quarters.

In the Bay of Fundy, the catch of moult group 1 lobsters is high in areas traditionally associated with recruit-based fisheries. The analysis also illustrates the current high catches of moult group 1 lobsters in Annapolis Basin and the adjacent coastal area, as well as in the upper Bay of Fundy. Number of moult group 1 lobsters landed per 10-min grid exceed 200,000 off southern Grand Manan (Figures 22 and 23). In comparison, numbers of moult group 1 lobsters landed in inshore waters of LFA 34 reach 500,000 per 10-min grid (Pezzack et al 2001).

Although absolute number landed is lower (maximum of approx. 60,000 lobsters per grid) the distribution of moult group 2 lobsters shows more consistency across the Bay of Fundy fisheries (Figures 22 and 23). In contrast, numbers of moult group 3 and greater lobsters are clearly highest in the lower Bay of Fundy, estimated at up to 54,000 per 10-min grid in LFA 38, as compared to maxima of 21,000 and 27,000 in LFA 36 and 35, respectively.

Catch composition was also aggregated on an LFA basis, and for the Bay of Fundy as a whole for both fishing seasons. All catch compositions are displayed in the same manner. Catch curves are provided for each LFA by fishing quarter separately, then for the fishing season as a whole. This data is displayed by 1 mm CL size increments. Figures 24, 25, and 26 provide an indication of the differential effect of the timing of the minimum size increases in the three LFA's during the 1998/99 fishing season. For LFA 35, the catch of 81 mm lobsters (estimated at 33,855 lobsters) is restricted to the Fall 1998 quarter, resulting in a stepped appearance in the fishing season catch curve (Fig. 24). In contrast the catch of 81 mm CL lobsters in the LFA 36 fishery (at 75,590 lobsters) reflects the absence of a similar size increase (Fig. 25). For LFA 38 in the 1998/99 fishing season, the first recruited size class is 83 mm CL lobsters (Fig. 26). The resulting catch curve for the three LFA's

combined reiterates this stepped nature of landings in the 81-83 mm CI size range (Fig. 27; see also Table 7).

The subsequent size increase schedule for the 1999/00 fishing season can be followed similarly (Figures 28-30 for individual LFA's; Fig. 31 for Bay of Fundy). This catch curve analysis allows a first level approximation of the total conservation of 81-83 mm lobsters due to minimum size increases over the two fishing seasons (Table 7).

In general terms, the catch analysis (Table 7) suggests that approximately 40,000 lobsters of each 1 mm size category (81, 82, and 83 mm CL) were available to be taken in the Fall fishery, and 30,000 in the following Spring fishery in each LFA in the two fishing seasons. Taking into account the timing of the move to a minimum carapace length of 82.5 mm CL in each LFA, LFA 38 is estimated to have avoided the capture of approx. 280,000 81 - 82 mm lobsters over the two fishing seasons. Using the estimated catches of 81 – 82 mm CL lobsters prior to the 82.5 mm CL minimum size, LFA 35 is estimated to have taken 140,442 81-82 mm CL lobsters, and LFA 36 is estimated to have caught 208,257 lobster of this size range over the two fishing seasons. Note that this analysis of effects of the conservation program does not include an estimate of the conservation value of the v-notching program in LFA 36. During the two fishing seasons LFA 36 had a voluntary v-notching program, but there were no regulations in place to prohibit the landing of v-notched lobsters in the adjacent LFA 35 and LFA 38 fisheries.

While the catch analysis can be used in a similar manner to evaluate the potential conservation value of various specific size regulations, it can also be used to provide a more general assessment of the catch composition in relation to moult group categories. For each LFA and fishing season (Figures 24-26; 28-30), the total catch is presented in terms of the number of lobsters landed from each of the three moult groups, and the percentage of those lobsters taken in each fishing quarter. Thus, for the 1998/99 fishing season in LFA 35 (Fig. 24) approx. 919,000 lobsters in moult group 1 are estimated to be landed, of which 51% are taken in the Fall fishery. The catch of 110+ lobsters is estimated at approx. 117,000, of which 35% are taken in the Fall, 33% in the Spring, and 32% in the Summer (or more specifically during July when LFA 35 is the only fishery open in the Bay of Fundy).

For the Bay of Fundy as a whole, similar moult group comparisons are made for each fishing season (Figures 27 and 31). In this case, the number of lobsters landed in each moult group is presented, as well as the percent taken by each of the LFA's. Thus, for the 1998/99 fishing season, of approx. 2.38 million moult group 1 lobsters landed, LFA 35 took 39%; LFA 36 took 35%, and LFA 38 accounted for 26%. Of the approx. 378,000 110+ lobsters landed, LFA 38 is estimated to have taken 40%.

A more detailed, tabular summary of the catch composition across the LFA's is provided for each fishing season in Tables 8 and 9. This analysis shows differences in the percentage composition of landings by moult group, with LFA 38 having both a high percentage of moult group 1 lobsters in the catch, as well as the highest percentage of moult group 3 lobsters (16.1 and 14.3% in the 1998/99, and 1999/00 fishing seasons, respectively). This may be a true reflection of catch composition, or a bias due to the fact that fisheries sampling data for LFA 38 is based principally in two very distinct fisheries: the recruit-based southern Grand Manan fishery, and the deepwater fishery targeted at migratory lobsters off eastern Grand Manan.

Overall, the catch in LFA's 35-38 is less dependent on first moult group animals (at approx. 65% by number of lobsters landed) than the adjacent LFA 34 fishery (estimated at 86% by Pezzack et al 2001; Tables 8 and 9). Approximately 18 million first moult group lobsters are landed each fishing season by the LFA 34 fishery, considerably more than the estimated 2 million lobsters of this size category landed by LFA's 35-38. However, numbers of third molt group and greater lobsters landed by LFA's 35-38 are more comparable to those in the catches from LFA 34 and 41 (Table 10).

Issues and uncertainty: This preliminary analysis of the spatial distribution of catch by moult groups in two fishing seasons is speculative due to the assumption-based approach of allocating landings to grids. Considerable work has been undertaken since 1998 to determine the appropriate spatial and temporal resolution of catch size structure needed to accurately translate landings to estimates of removals from the fishable stock. The recent ability to access the landings database at a finer scale of resolution has been an important tool in refining fishery-sampling strategies, though uncertainties in landings data quality are still being investigated. Additionally, the requirement to be able to sample catches in a cost-effective manner over the longer-term needs to be addressed. The landings expansion could be based alternatively on an enhanced port sampling of catches if general location of sampled catch could be routinely documented.

Skewed sex and size ratios from small sample sizes could affect the estimated catch in number of each sex. For this analysis numbers landed are presented in terms of males and females combined.

The estimated catch composition in the Bay of Fundy, at 65% in the first moult group (by number), has to be considered in light of:

1) the recent expansion in total landings from approximately 1000 tonnes in the early to mid-1990's to 2500 tonnes in the late 1990's;

2) evidence presented herein and by Lawton et al (2001) of a significant recruitment event influencing these fisheries during the 1990's.

There was a similar high level of fishery sampling conducted in the Bay of Fundy fishery during the late 1970's, and it may be possible to construct a similar catch profile from that period, in order to estimate the relative numbers of lobsters landed from the different moult groups.

F and exploitation rate

Length-based cohort analysis (LCA): Use of LCA for LFA 35 to 38 in the 1998 assessment generated substantially lower estimates of F and exploitation rate (A) than were provided in earlier fishery assessments (Lawton and Robichaud, 1992a). The earlier, higher exploitation rate estimates were used by the FRCC in their review of the Atlantic lobster fishery (FRCC, 1995). The moult group comparison techniques used in those assessments provided exploitation rate estimates in the range 60-85%. Estimates provided by Lawton et al. (1999) from LCA range from between 39 - 70% for LFA 35, 49-56% for LFA 36, and 54-66% for LFA 38. Using then available size frequency data for the three LFA's, and reported landings, a combined Bay of Fundy LCA was conducted yielding new estimates of exploitation rate in the range of 49-63% over the period 1988 to 1995. The pattern of fishing mortality and exploitation rate generated by these analyses for the period 1988 to 1993, when landings were more stable for the Bay of Fundy, were used in the calculations of egg per recruit and the impacts of proposed management changes. For the period 1998 to 1993 average exploitation rate for the Bay of Fundy-level analysis was 53%. The LCA analysis was not updated in this assessment due to the continued indication of recruitment variation.

Issues and uncertainty: While LCA had been used routinely in US lobster assessments, the 1998 assessment cycle represented its first widespread application in Canadian lobster fisheries. The existing sampling of length composition in most lobster fisheries was very limited. For the last assessment it was not possible to break the landings data down much beyond the LFA level, and often single samples of length frequency from at-sea samples were used to model Fall and Spring landings data. However, comparison of the LCA results with those from other F estimation approaches (Leslie analysis, moult group comparison, mark-recapture studies) in other LFA's indicated some robustness and comparability in the estimates. The lower F and A estimates for the

Bay of Fundy were consistent with general results from the first application of the LCA approach in other lobster fishing areas.

E/R Analyses

Current status in relation to doubling E/R: As noted under methods, no new e/r analyses have been undertaken for this assessment due to the uncertainty of estimating underlying exploitation rates in fisheries which are in the midst of a significant recruitment event. In the last assessment, e/r analyses were produced using two estimates of exploitation rate, which provided a broad range of projected benefits. Significant increases in minimum size (if this were adopted as the sole approach) were estimated to be required, beyond 86 mm CL, which by itself provided only an approximate 50% increase at an exploitation rate of 53% (Lawton et al 1999). Management measures that included a move to then US minimum size, 83 mm CL, were projected to require additional measures (e.g. maximum size regulations; v-notching) to achieve the target doubling (discussed by Lawton et al 1999).

Issues and uncertainty: One of the management measures included in the DFO default conservation plan was the imposition of a maximum size regulation on female lobsters, scheduled for the final year of the conservation plan. Following the last stock assessment lobster fishers, particularly those in LFA 38, raised significant concerns on realized benefits from adopting this conservation management approach (Appendix 1). Projected benefits of a maximum size measure, as developed through e/r modelling, do not recognize differential effects on segments of the fishing fleet that have directed fisheries for large lobsters, nor potential for redistribution of fishing effort to inshore grounds by fishers displaced by such a management measure.

Stock Structure

Lawton et al (1999) discussed key aspects of stock structure of lobsters in the Bay of Fundy, and only a brief summary is provided in this document.

Lobster production characteristics: While a portion of the Bay of Fundy fishery is reliant on lobsters migrating into fishing areas at different times of the year there are, nonetheless, centres of benthic lobster production in the Bay, as evidenced by the presence of high numbers of juvenile lobsters in the trap fishery, and in benthic biological censuses (e.g. Lawton et al., 1995; Lawton et al 2001). Examples of these areas are southern Grand Manan and the Fundy Isles/S.W. New Brunswick coastal area. Historically, the fishery in the upper Bay of Fundy was considered to be principally reliant upon seasonal immigration of later benthic stages of lobsters (e.g. Robichaud and Campbell, 1991). However, fisheries monitoring during the 1990's, principally in the Alma area, documented a dramatic change in trap size-frequency distribution which suggests that local benthic production in the upper Bay has increased.

Diving surveys on inshore lobster habitats were conducted in the Fundy Isles Region of the Bay of Fundy between 1989 and 1993. The presence of significant numbers of small juvenile lobsters in shallow water habitats there indicated a lobster nursery area function (*sensu* Lawton and Robichaud, 1992b). In some inshore locations within the Bay of Fundy, for example North Head, St. Martins and Alma, N.B., seasonal aggregations of berried female lobsters have been documented.

During 2000 new diving and trapping studies have been intitiated which allow for decadal-scale comparisons of lobster population structure in similar geogrpahical locations, and with respect to diving studies, on similar benthic habitats. These studies are discussed by Lawton et al (2001), and indicate a pattern of increased abundance of lobsters over summer months in inshore waters of the lower Bay of Fundy in both nursery and spawning areas.

Lobster movement: Recent results on lobster movement in the Bay of Fundy (Lawton et al. 1995; Robichaud and Lawton 1997) are consistent with those obtained in earlier tagging studies (Campbell 1986; Campbell and Stasko 1985, 1986) which demonstrate substantial mixing throughout the Bay of Fundy and along the Maine coast. The total percentages of tag returns in the various tagging studies varied between 13% and 20%.

Issues and uncertainties: While there are centers of local production (benthic settlement and growth of lobsters), much of the Bay of Fundy lobster fishery has developed over time to capitalize on well marked seasonal and long distance movements of legal-size lobsters (Robichaud and Campbell 1991; Campbell and Stasko 1986).

The Bay of Fundy lobster fishery was relatively stable during the 1980's to mid 1990's. In particular, it did not show a rapid expansion of landings (doubling within 5 years) until very recently. The fact that this dramatic shift occurred approximately a decade after a similar initial rapid expansion phase in the LFA 34 fishery suggests a potential linkage between the two events, perhaps related to an increased larval subsidy from the outer Gulf of Maine.

The general conclusion is that the Bay of Fundy lobster fishery should be considered a component of a Gulf of Maine lobster metapopulation. The degree to which it represents a source of larval production for adjacent areas (such as the Maine coast), or a sink (receiving the benefits of larval production occurring outside the Bay of Fundy) is still not known. There is a need to increase the capability of physical and biological oceanographic models of the Gulf of Maine system to model the Bay of Fundy as an integral component of the system.

General issues and uncertainty

Resource management of lobsters in the Gulf of Maine is complicated by complexity inherent in the lobster population itself, and that imposed by multiple management jurisdictions (2 Canadian Provinces; Federal inshore and offshore management areas; state and federal jurisdiction in the US portion of the Gulf of Maine). The relative importance of intrinsic and extrinsic larval production to the Bay of Fundy is not known, but available evidence from oceanographic modeling and benthic studies on movement demonstrates that management of these three LFA's will affect, and be affected by management change in adjacent areas.

Given the recent catch history in the Bay of Fundy lobster fisheries, and uncertainty over the final realized benefits of default measures in the e/r doubling plan, Industry has been reluctant to adopt additional measures within the current 4-year plan beyond the initial minimum size increase, and v-notching. The proposed maximum size regulation, in particular, is very controversial with Industry due to the differential impacts it would have on fleet segments, and the potential for relocation of fishing effort in some LFA's, which would reduce its overall effectiveness.

Additionally, LFA's 36 and 38 are contending with uncertainty over immediate and longer-term consequences on lobster populations and sensitive fishery habitats in connection with the continued development of the marine aquaculture industry in the lower Bay of Fundy.

New estimates of the catch size structure in different geographical areas of the Bay of Fundy, and estimates of the total removals of lobsters should enable better estimates to be made of the potential impacts of various new conservation management options. The multiple, and interacting nature of the issues facing the Bay of Fundy lobster industry require a considered approach to conservation management which is predicated by regional circumstance, uncertainty, and risk.

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Table 1. Elements of the lobster fishery management regime in the Bay of Fundy (LFA's 35, 36, and 38). (A) Number of license holders by license category and trap limits per license. Information as of Mar 31, 2001. (B) Fishing season opening and closing dates. (C) Recent minimum size and v-notch regulation changes.

(A)

LFA	License details	A licenses (full time)	Partnership (full time)	B licenses (part-time)
35	Number	96	-	-
	Trap limit	300	-	90
36	Number	161	7	2
	Trap limit	300	450	90
38	Number	82	26	1
	Trap limit	375	563	113

(B)

LFA	Fall season opening date	Fall season closing date	Spring season opening date	Spring season closing date
35	Oct. 15	Dec. 31	April 1	July 31
36	2nd Tues. in Nov.	Jan 14	March 31	June 30
38	2nd Tues. in Nov.	Open through winter	Open through winter	June 30

(C)

Regulation change	LFA 35	LFA 36	LFA 38
Min size increase to 81.8 mm	Spring 1999	Fall 1999	No intermediate step
Min size increase to 82.5 mm	Spring 2000	Fall 2000	Fall 1998
V-notching program		Spring 1999	
Prohibition on landing v-notch	Spring 2001		Spring 2001

Table 2. Size categories used by LFA 35 fishers to record lobsters caught in commercial traps.

Size Interval on Gauge	Carapace Length Range (mm)	Moult Group
1	< 75	Shorts
2	75-80	Shorts
3	81-87	1
4	88-94	1
5	95-101	2
6	102-108	2
7	109-115	3
8	116-122	3
9	123-129	4
10	130-136	4
11	> 136	5 and greater

Table 3. Landings series for the last 10 complete fishing seasons in the Bay of Fundy.

Seasonal* Landings (t)

Season*	1990-1991	1991-1992	1992-1993	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000
LFA 35	228	254	241	241	309	559	749	844	948	874
LFA 36	271	249	257	274	317	414	660	751	812	780
LFA 38	496	511	471	520	657	600	547	696	806	740
Total	995	1014	969	1035	1283	1573	1956	2291	2566	2394

*Fall to subsequent Spring fishery. 1999-2000 data should be considered preliminary.

Table 4. Frequency distribution information for berried female lobsters sampled during at-sea sampling program in the Bay of Fundy, 1978 - 2000. Frequency distributions presented graphically in Fig. 19. Samples are pooled from the ports of North Head, Alma, and Dipper Harbour over 5-year periods (3 years for most recent period).

Variable	Sample period				
	1998-2000	1993-1997	1988-1992	1983-1987	1978-1982
Number in sample	1224	963	1177	2030	6366
Median CW (mm)	111	113	114	122	121
Min. CW (mm)	79	82	83	87	85
Max. CW (mm)	204	197	185	193	197
% 81-94 mm CW	3.7	3.6	1.4	0.4	0.2
% 95-109 mm CW	38.1	34.3	30.3	16.3	14.4
% 110+mm CW	58.2	62.1	68.3	83.3	85.4

Table 5. Summary of LFA 35 Industry Catch sampling program. Entries are listed for each participating fisher by reference to home port or area of fishing activity.

	Spring 1997		Fall 1997	
	# Traps	# Lob.	# Traps	# Lob.
Location	Sampled	Measured	Sampled	Measured
Minas Basin	415	1401	0	0
Minas Basin	379	1347	0	0
Advocate Harbour	422	1312	0	0
Total	**1216**	**4060**	**0**	**0**
	Spring 1998		**Fall 1998**	
	# Traps	# Lob.	# Traps	# Lob.
Location	Sampled	Measured	Sampled	Measured
Minas Basin	534	1540	0	0
Minas Basin	204	926	135	817
Advocate Harbour	377	1137	110	645
Advocate Harbour	70	180	0	0
Alma	0	0	32	270
Annapolis Basin	0	0	90	372
Total	**1185**	**3783**	**367**	**2104**
	Spring 1999		**Fall 1999**	
	# Traps	# Lob.	# Traps	# Lob.
Location	Sampled	Measured	Sampled	Measured
Parrsboro	417	1308	0	0
Parrsboro	212	1038	80	354
Alma	160	576	0	0
Alma	69	121	0	0
Advocate Harbour	225	583	135	475
Total	**1083**	**3626**	**215**	**829**
	Spring 2000		**Fall 2000**	
	# Traps	# Lob.	# Traps	# Lob.
Location	Sampled	Measured	Sampled	Measured
Parrsboro	159	733		
Advocate Harbour	279	467		
Total	**438**	**1200**	**0**	**0**

Table 6. Catch rates of pre-recruit lobsters 75-80mm CL observed in DFO and Industry sea sampling in upper Bay of Fundy, 1998-2000. Data are number of 75-80mm CL lobsters per trap haul for months where a minimum of 20 trap hauls was measured.

DFO Sea Sampling

Port	1998						1999						2000					
	May	June	July	Oct.	Nov.	Dec.	May	June	July	Oct.	Nov.	Dec.	May	June	July	Oct.	Nov.	Dec.
Alma				2.23			0.55	1.11	1.17	1.08	0.77		0.77		0.72	0.83	0.79	0.30
Advocate			0.57	1.48				0.39	0.91	0.71			0.41	0.32	0.32	0.74	0.82	
Parrsboro			1.65	0.90				1.16	0.53	0.39	0.21			0.46	0.30	0.43	0.41	
Scotts Bay			0.42	1.10				0.62	0.55	0.40	0.32			0.78	0.65	0.70		
Parker's Cove										1.32	1.02					0.86	0.55	
Delap Cove			0.44	1.02				0.37	0.59	1.10	1.00			0.94	0.61			
Victoria Beach			0.41	0.89				0.52	0.39	0.56	0.54			0.58	0.69	0.80	0.61	

Industry Sea Sampling

Port	1998						1999						2000					
	May	June	July	Oct.	Nov.	Dec.	May	June	July	Oct.	Nov.	Dec.	May	June	July	Oct.	Nov.	Dec.
Alma							0.49	1.00	0.83									
Advocate		0.69	0.72	1.48	1.00			0.69	0.61	0.54	1.05			0.34	0.34			
Parrsboro	0.61	0.85	1.03	1.13	0.86	1.00	0.82	1.09	0.64	0.30	0.43	0.00	0.51	0.83	1.00			
Scotts Bay																		
Parker's Cove																		
Delap Cove																		
Victoria Beach				1.13														

Table 7. Estimated removals of 81-83 mm CL lobsters over the fishing seasons 1998-99 and 1999/00 in LFA's 35, 36, and 38.

LFA and CL Category	Fall 1998	Winter-Summer 1999	Fall 1999	Winter – Summer 2000	Total
LFA 35					
81	33855	0	0	0	33855
82	34049	37950	34588	0	106587
83	40511	35402	41608	34932	152453
LFA 36					
81	51909	23681	0	0	75590
82	42345	21650	37842	30830	132667
83	38941	21600	39786	27793	128120
LFA 38					
81	0	0	0	0	0
82	0	0	0	0	0
83	43311	27328	57255	30091	157985

Table 8. Estimated numbers of lobsters (male and female combined) landed during the 1998/99 fishing season, including adjustments for differential timing of minimum size increases.

(A) Numbers landed by moult group by each LFA with the percentage of the total number of each moult group taken by each LFA.

1998/99 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	919119	834205	623397	2376721.00
95-109	402145	254439	169368	825952.00
110+	116741	109365	151609	377715.00
Total Legal	1438005	1198009	944374	3580388.00

1998/99 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	39%	35%	26%	2376721.00
95-109	49%	31%	21%	825952.00
110+	31%	29%	40%	377715.00
Total Legal				3580388.00

(B) Percentage distribution of moult groups in the landings of each LFA and in all LFA's combined.

1998/99 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	63.9%	69.6%	66.0%	66.4%
95-109	28.0%	21.2%	17.9%	23.1%
110+	8.1%	9.1%	16.1%	10.5%
Total Legal	1438005	1198009	944374	3580388.00

Table 9. Estimated numbers of lobsters (male and female combined) landed during the 1999/00 fishing season, including adjustments for differential timing of minimum size increases.

(A) Numbers landed by moult group by each LFA with the percentage of the total number of each moult group taken by each LFA.

1999/00 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	829325	700961	664352	2194638.00
95-109	394101	253005	171223	818329.00
110+	94546	122943	139268	356757.00
Total Legal	1317972	1076909	974843	3369724.00

1999/00 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	38%	32%	30%	2194638.00
95-109	48%	31%	21%	818329.00
110+	27%	34%	39%	356757.00
Total Legal				3369724.00

(B) Percentage distribution of moult groups in the landings of each LFA and in all LFA's combined.

1999/00 Fishing Season Summary

mmCL	LFA 35	LFA 36	LFA 38	Combined
81-94	62.9%	65.1%	68.1%	65.1%
95-109	29.9%	23.5%	17.6%	24.3%
110+	7.2%	11.4%	14.3%	10.6%
Total Legal	1317972	1076909	974843	3369724.00

Table 10. Comparison of LFA 34, Bay of Fundy LFA's (35, 36, and 38), and LFA 34 in terms of number of lobster landed and percentage composition of catch in three moult group categories.

Number Landed per Moult Group

Season	LFA	81-94	95-109	110+	Total by LFA
1998/99	34	17933218	2428129	822436	21183782
	35-38	2376721	825952	377715	3580388
	41	70193	140743	249434	460370
Total by moult Group		20380132	3394824	1449585	25224540
1999/00	34	18245090	2498477	847187	21590753
	35-38	2194638	818329	356757	3369724
	41	103673	197486	289868	591027
Total by Moult Group		20543401	3514292	1493812	25551504

Percent of each molt group Landed by LFA or LFA Grouping

Season	LFA	81-94	95-109	110+
1998/99	34	88.0%	71.5%	56.7%
	35-38	11.7%	24.3%	26.1%
	41	0.3%	4.1%	17.2%
1999/00	34	88.8%	71.1%	56.7%
	35-38	10.7%	23.3%	23.9%
	41	0.5%	5.6%	19.4%

Figure 1. Bay of Fundy LFA's with approximate boundaries. LFA 37 is a buffer zone between LFA's 36 and 38.

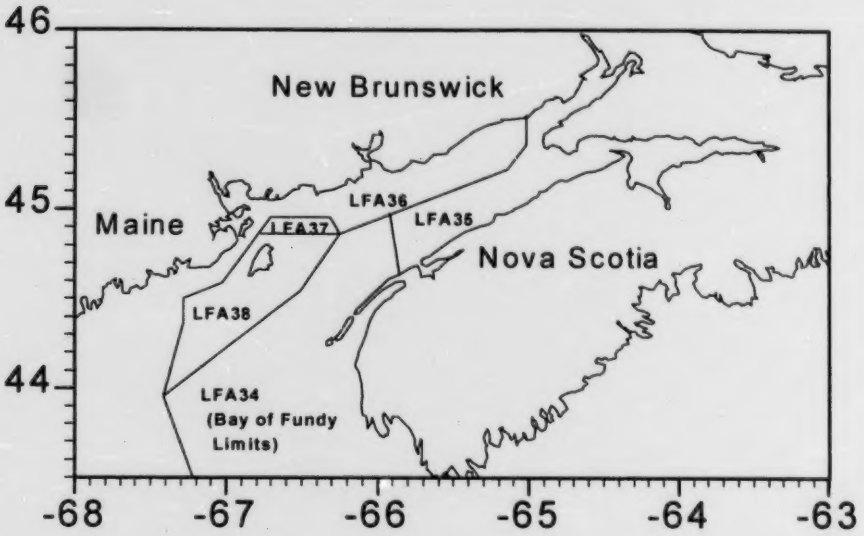


Figure 2. Statistical District Boundaries in the Bay of Fundy.

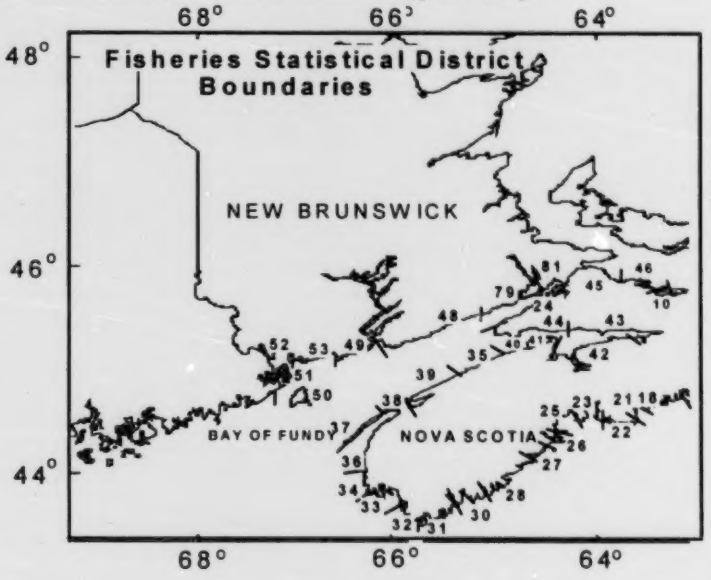


Figure 3 A. Geographical areas in the Bay of Fundy referenced in text, and the locations of 4 principal at-sea sampling ports (Alma, Dipper Harbour, North Head, Seal Cove).

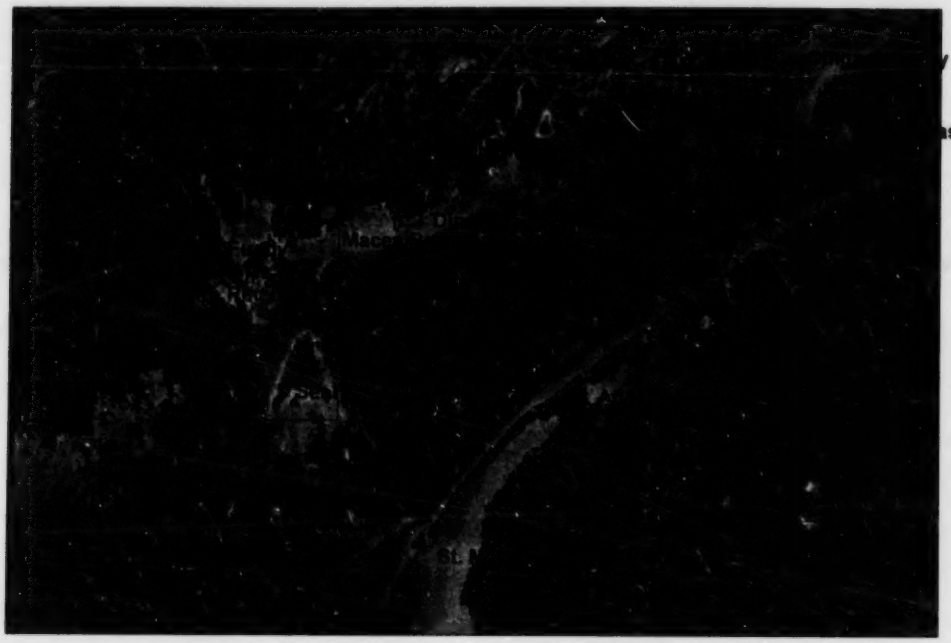


Figure 3 B. Counties in Maine.

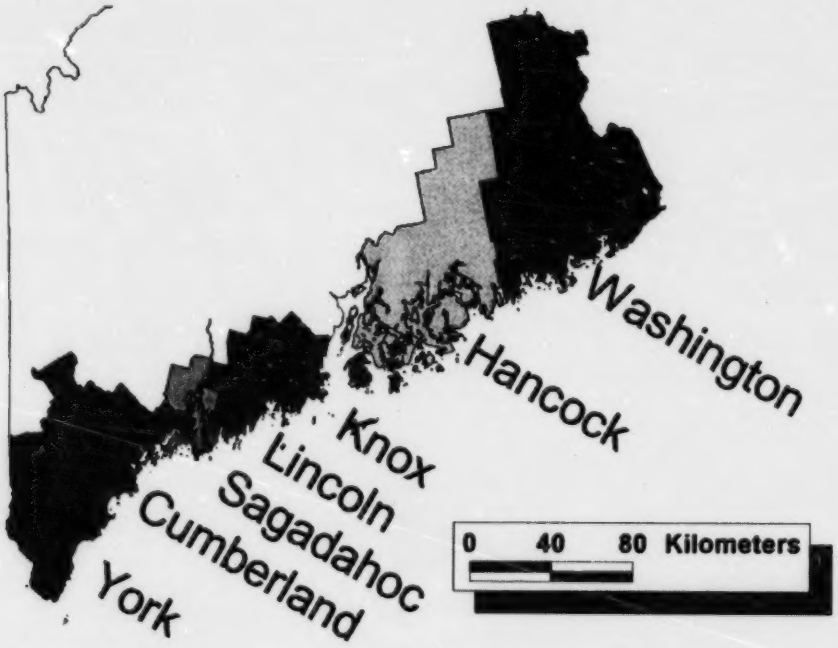


Figure 4. Twelve groupings of grid squares used for allocating size frequencies to landings data (Top panel). The numbering system for the 10-min grids (Lower panel) was developed in 1998 for lobster fishery catch settlement reports and has been in use in LFA 34, since Nov. 1998. Group designations extend beyond boundaries of specific LFA's to access additional information in the at-sea sample database. Group definitions also extend into the middle Bay of Fundy.

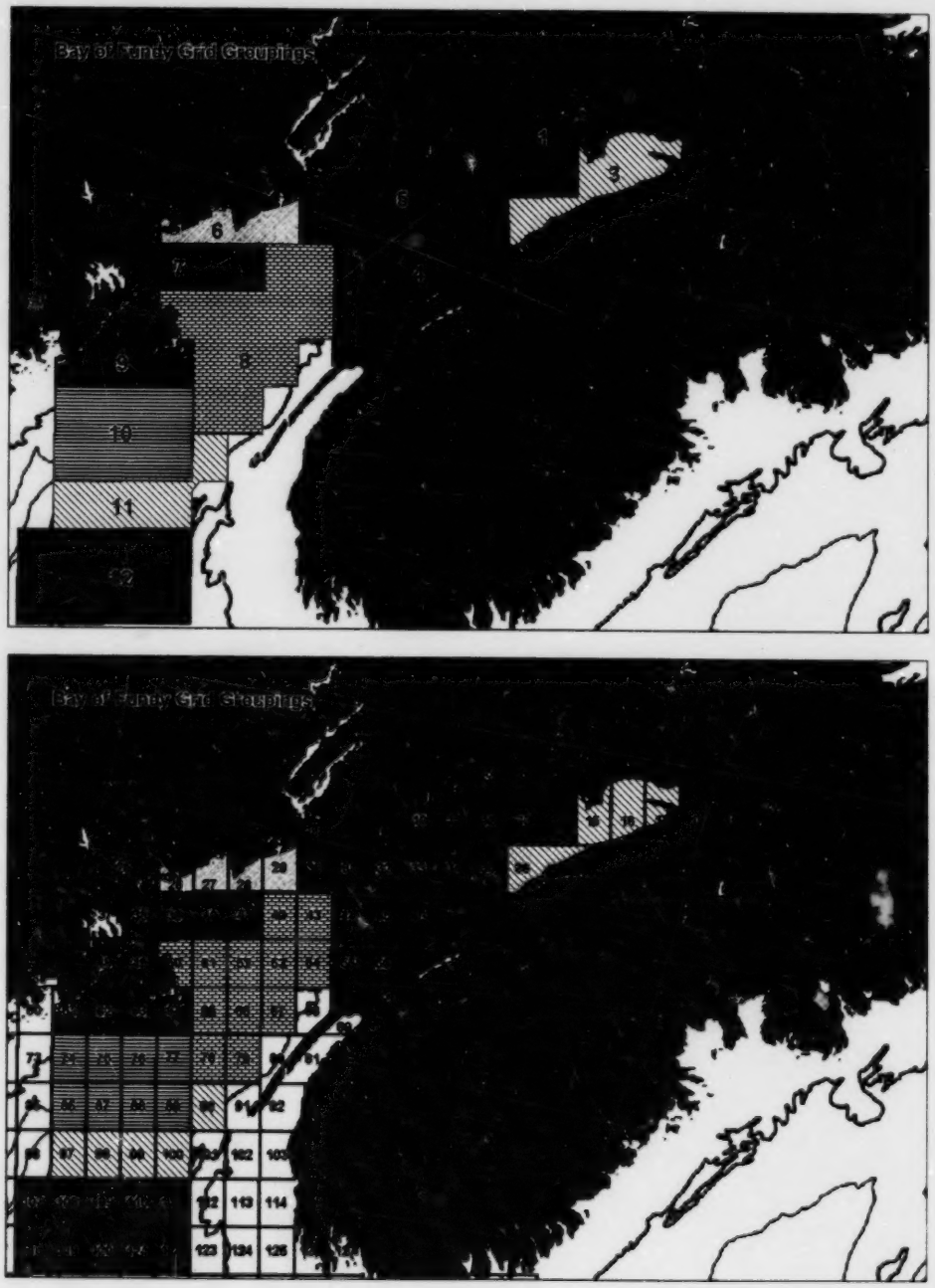


Figure 5. Historical landings from the Bay of Fundy (LFA's 35, 36, and 38). Data presented as annual landings from 1892 to 2000. Landings data are missing from some LFA's for early years of the fishery. See Williamson (1992) for information on historical data sources.

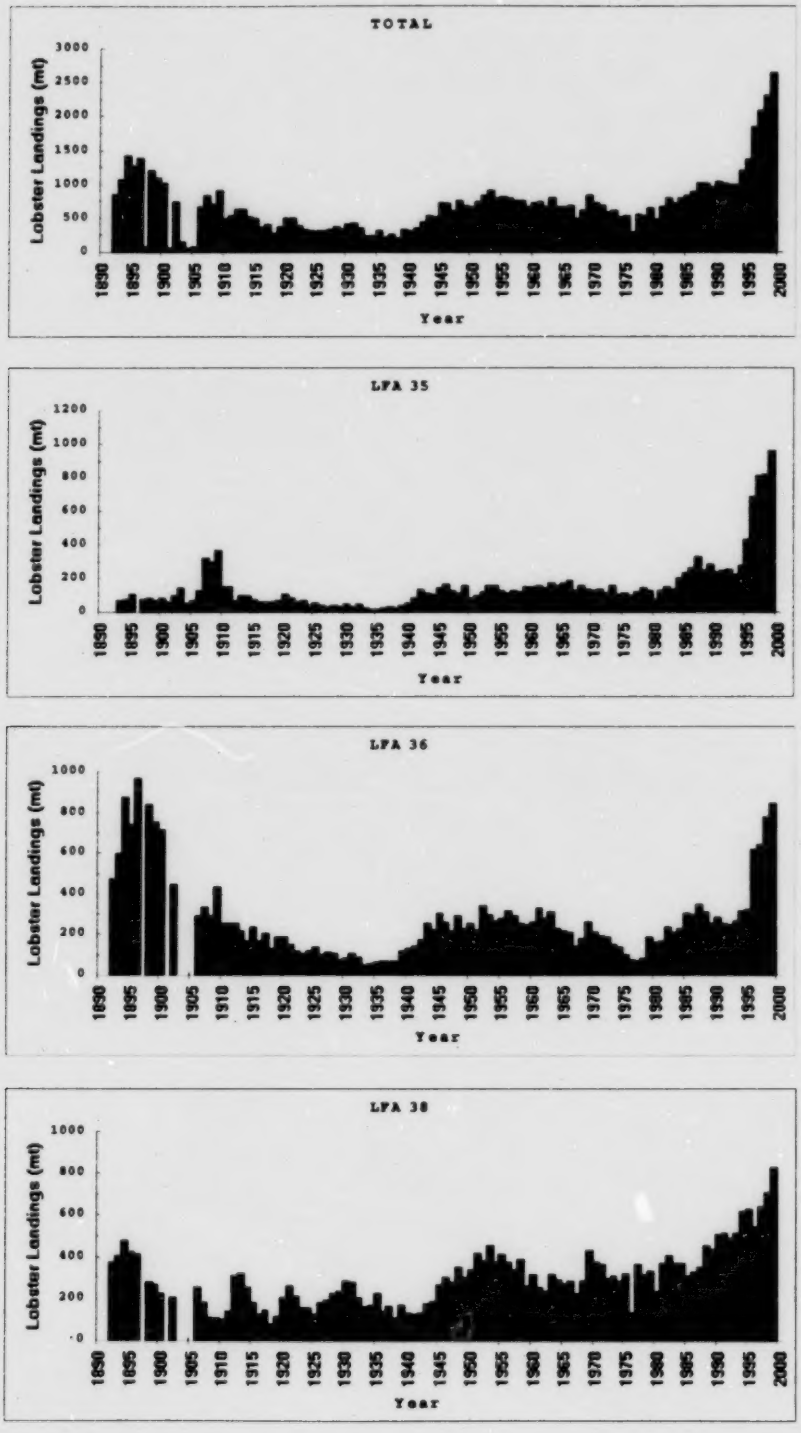


Figure 6. Seasonal landings from the Bay of Fundy (LFA's 35, 36, and 38) from the late 1940's to the 1999/2000 fishing season. Data presented as seasonal landings (from the opening of the Fall season in one year to close of the Spring season in the following year; season opening dates presented in Table 1). The percentage contribution of landings from each LFA to the seasonal totals is presented in the lower panel.

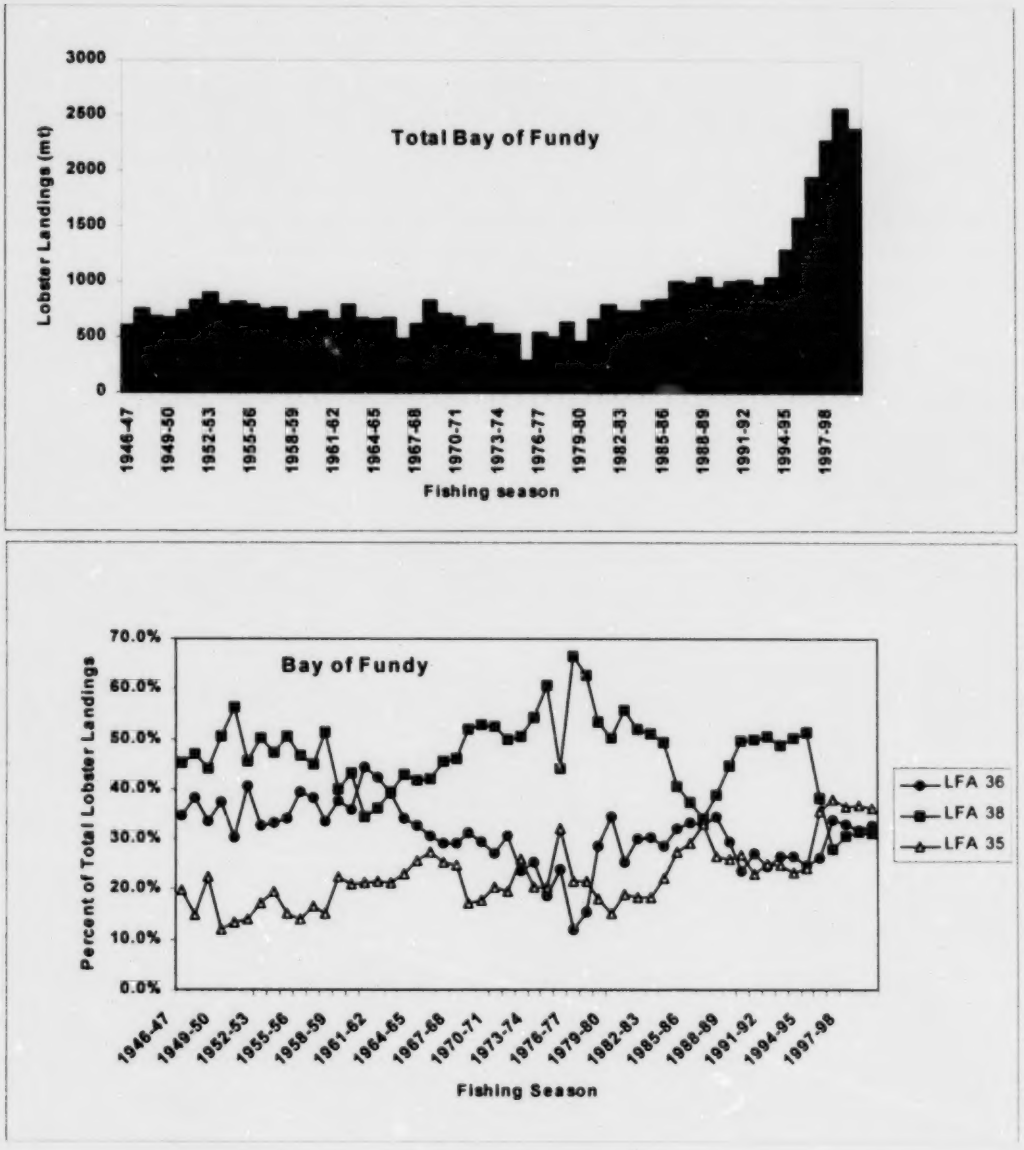


Figure 7. Seasonal landings from the Bay of Fundy (LFA's 35, 36, and 38) from the late 1940's to the 1999/2000 fishing season.

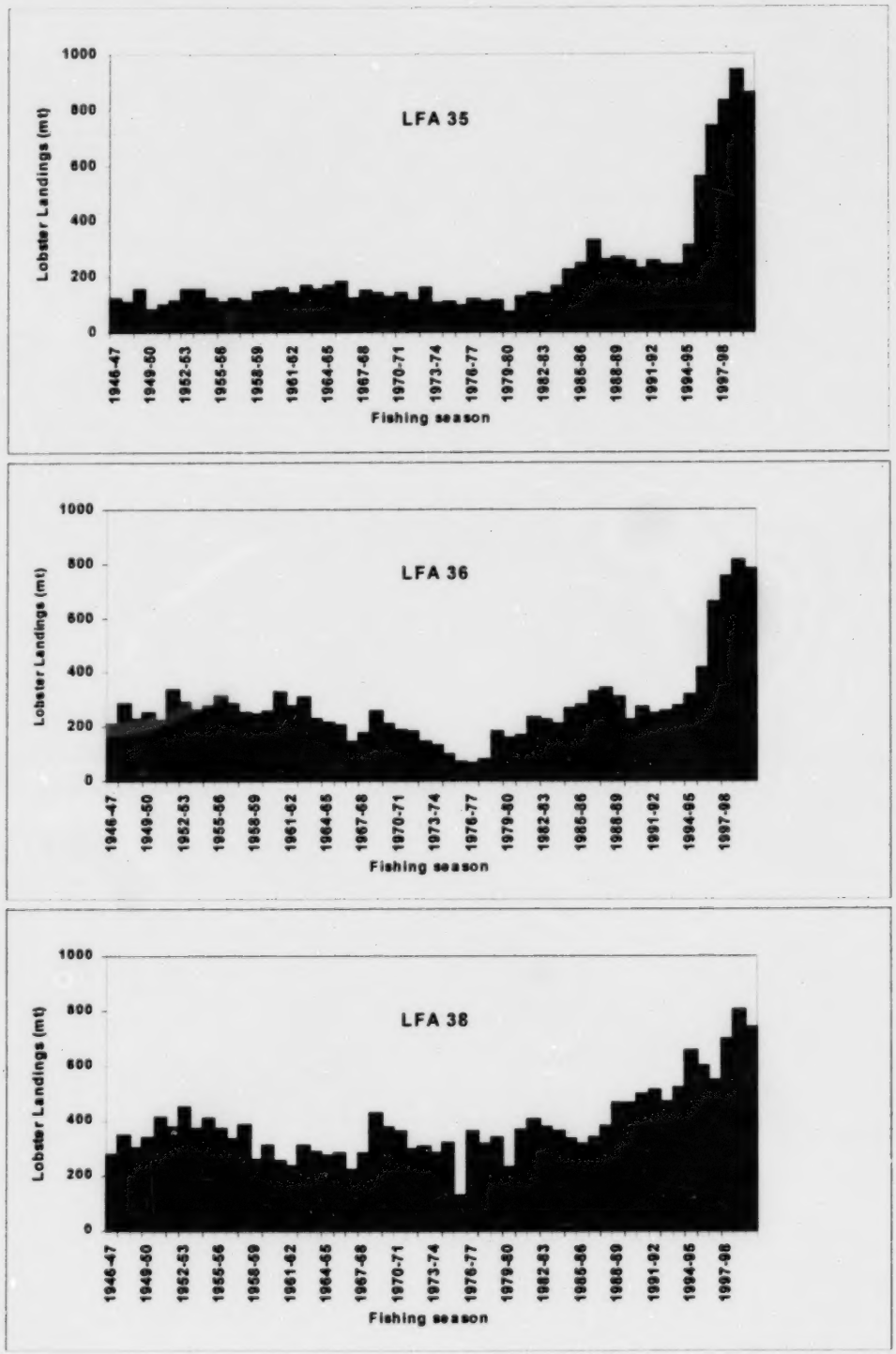


Figure 8. Landings trends in the Bay of Fundy and Approaches. Difference from 1983/84 season total landings in subsequent fishing seasons presented for groupings of Statistical Districts (STD) arrayed geographically from the upper reaches of the Bay of Fundy to Counties of Maine and STD's of southwestern Nova Scotia. Note the difference in scales for Minas Basin and Approaches, and Mid Bay – Nova Scotia (maximum of 16X base season landings), as compared to other STD or Maine County plots (maximum of 8X base season).

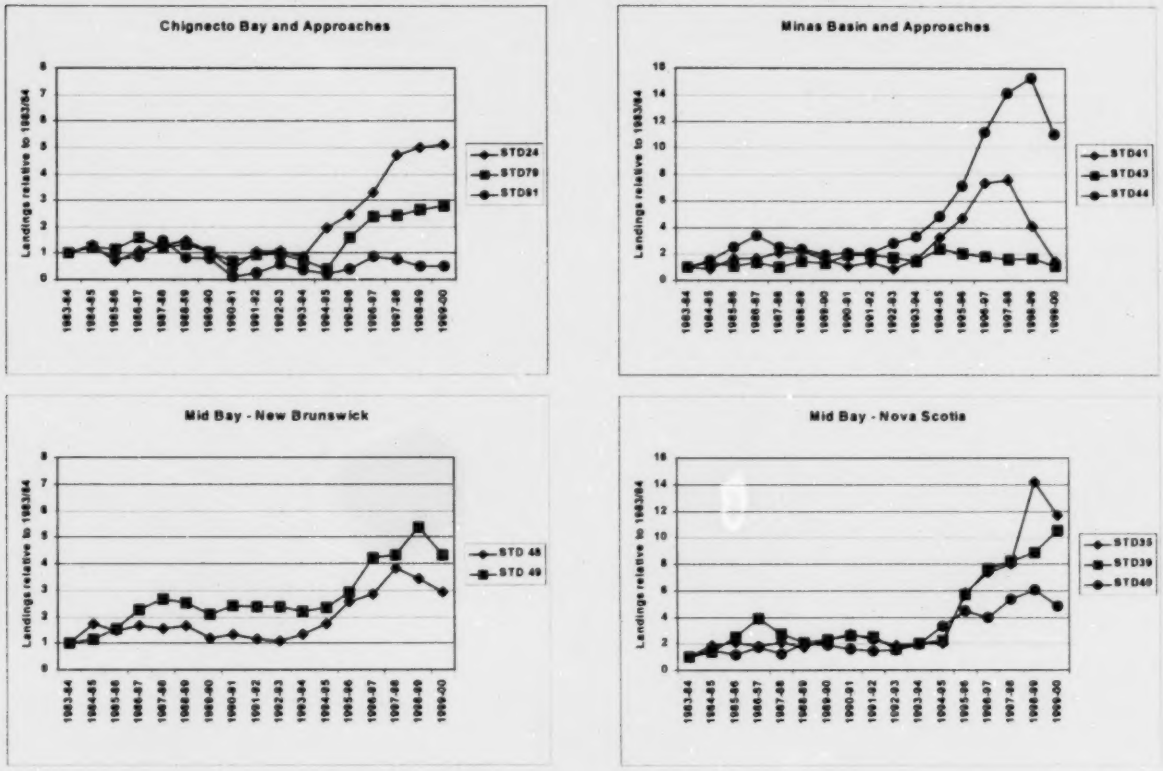
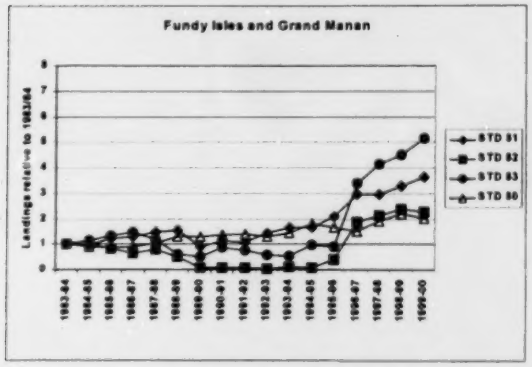
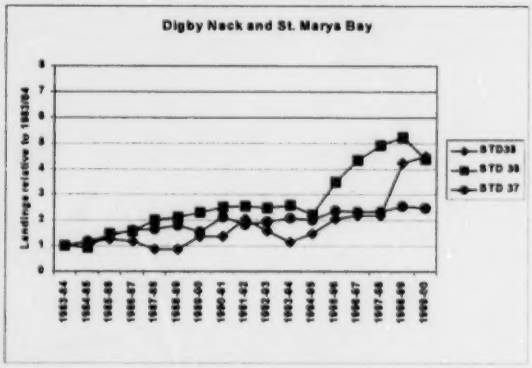
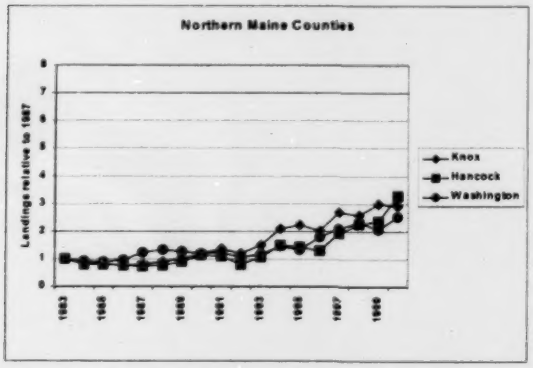
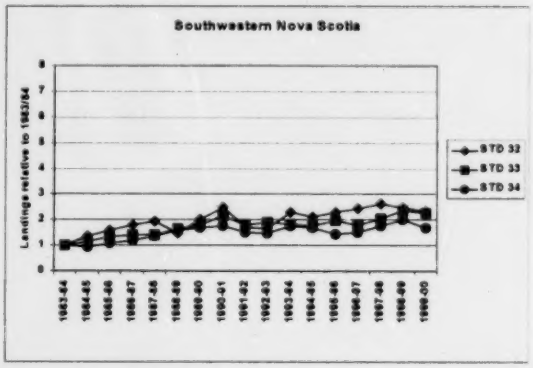


Figure 8 (cont.). Landings trends in the Bay of Fundy and Approaches. Difference from 1983/1984 season total landings in subsequent fishing seasons presented for groupings of Statistical Districts (STD) from the upper reaches of the Bay of Fundy to the Gulf of Maine. Note all plots below have a maximum of 8X base period landings. Landings for Maine counties are presented as annual landings relative to a base year (1983).









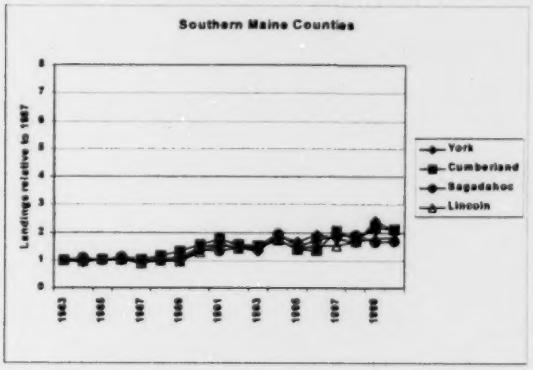
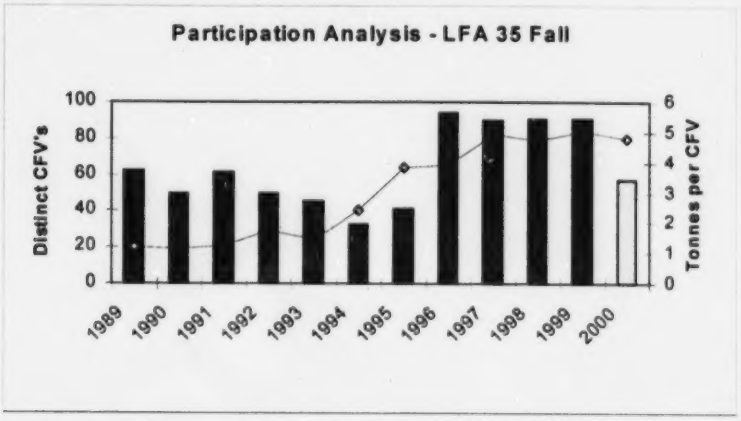
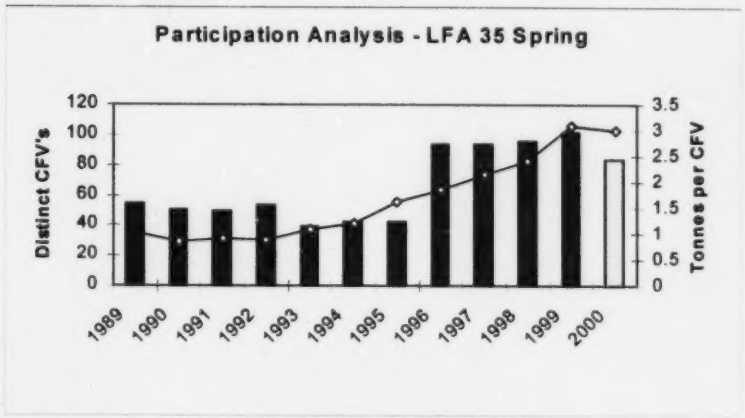


Figure 9. Fleet participation analysis for LFA 35 by fishing season quarter. The LFA 35 Summer period represents landings reports in July. See Table 1B for actual fishing season opening and closing dates. For each period landings identified to distinct CFV were used to develop values for number of distinct CFV's reporting landings (histogram), and average catch per CFV for the period (line). Data for 2000 should be considered preliminary.





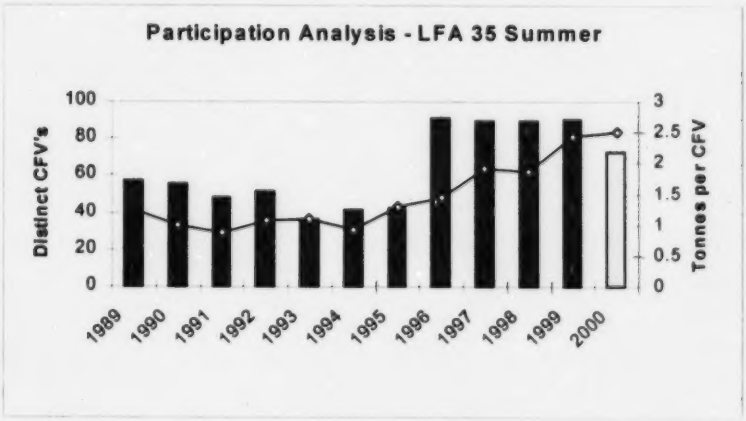
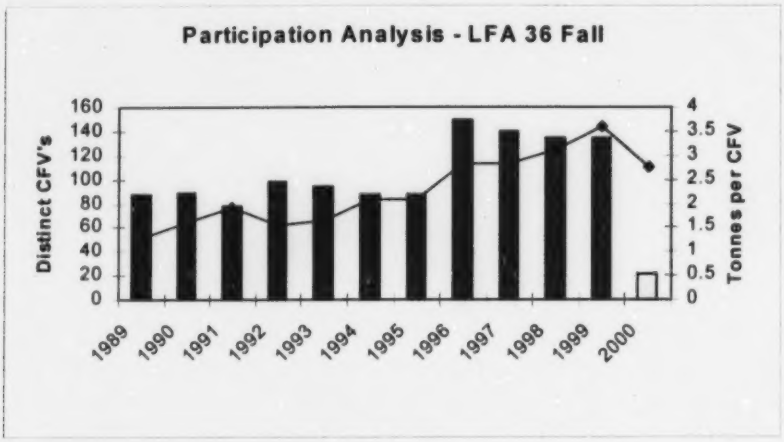
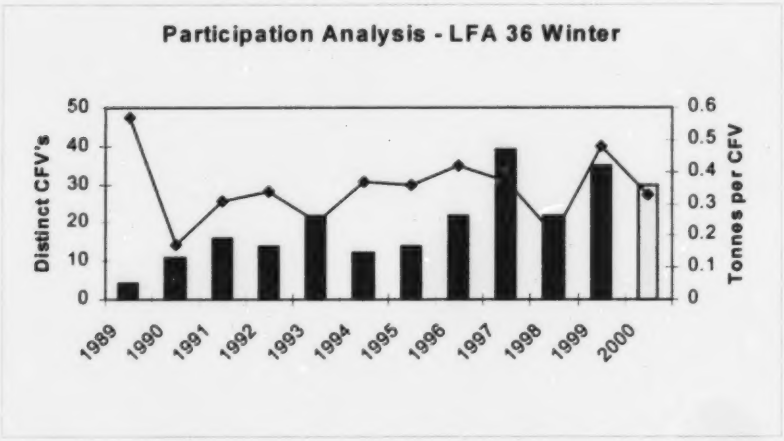


Figure 10. Fleet participation analysis for LFA 36 by fishing season quarter. See Table 1B for actual fishing season opening and closing dates. For each period landings identified to distinct CFV were used to develop values for number of distinct CFV's reporting landings (histogram), and average catch per CFV for the period (line). Data for 2000 should be considered preliminary.





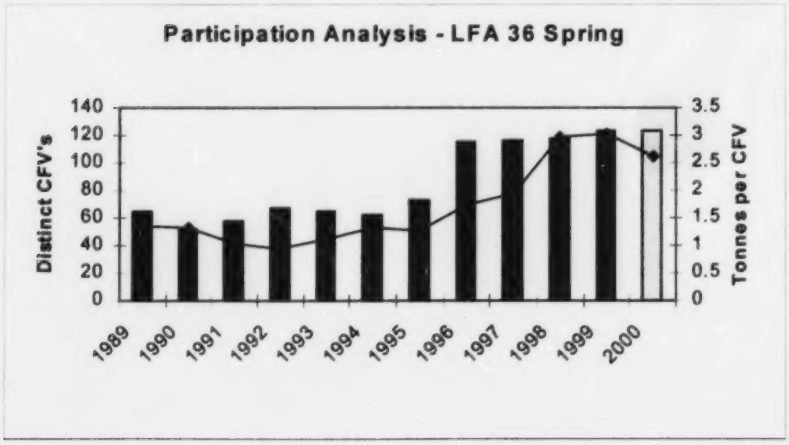
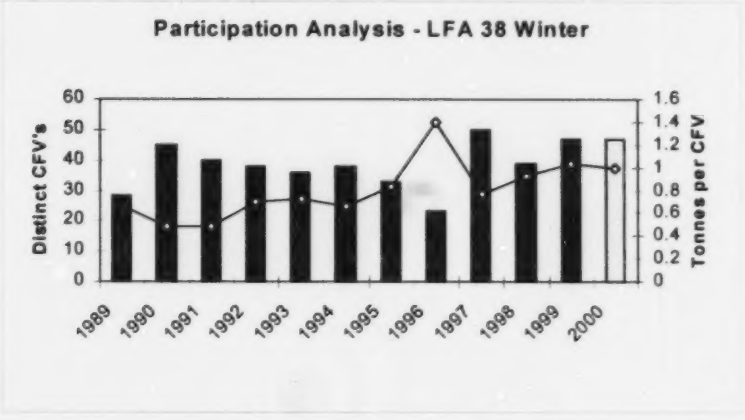


Figure 11. Fleet participation analysis for LFA 38 by fishing season quarter. Landings for LFA 38 in Winter represent landings throughout Jan to Mar when only a portion of the fleet is active. See Table 1B for actual fishing season opening and closing dates. For each period landings identified to distinct CFV were used to develop values for number of distinct CFV's reporting landings (histogram), and average catch per CFV for the period (line). Data for 2000 should be considered preliminary.



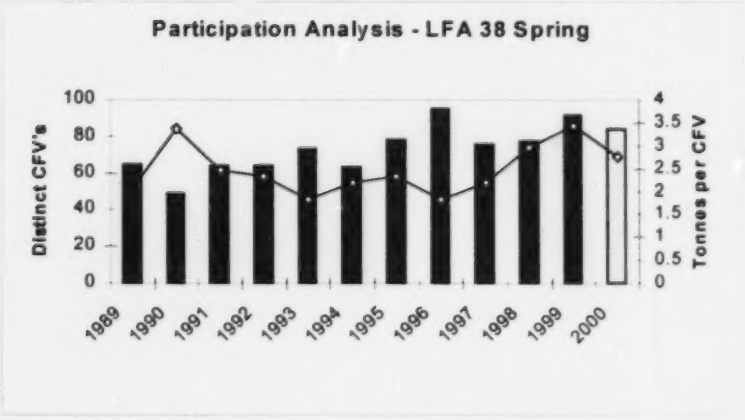


Figure 12. At-sea sampling size frequencies for fishing seasons 1990/91 to 1994/95 for Seal Cove (LFA 38).

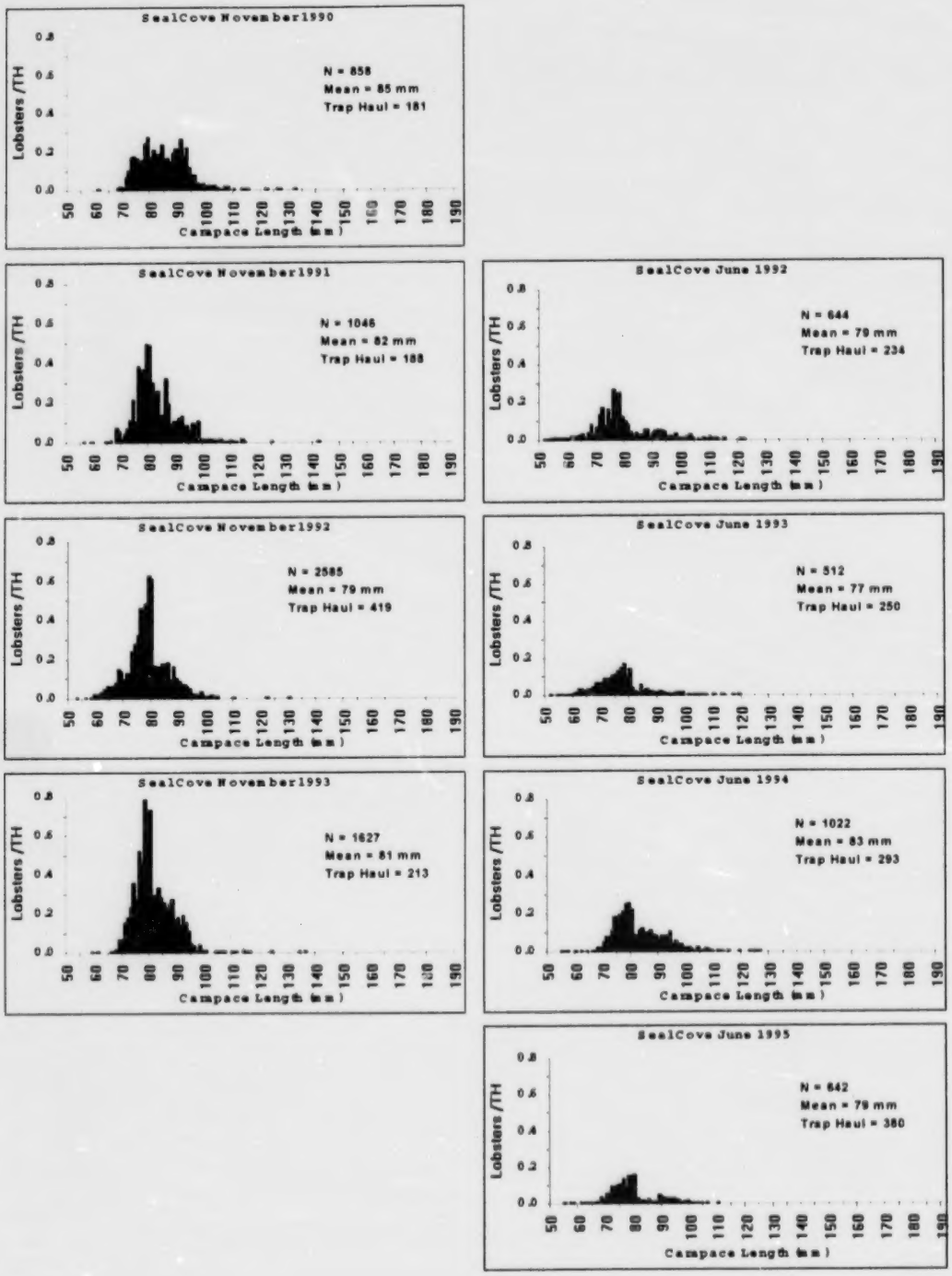


Figure 12 (cont.). At-sea sampling size frequencies for fishing seasons 1995/96 to 1999/2000 for Seal Cove (LFA 38).

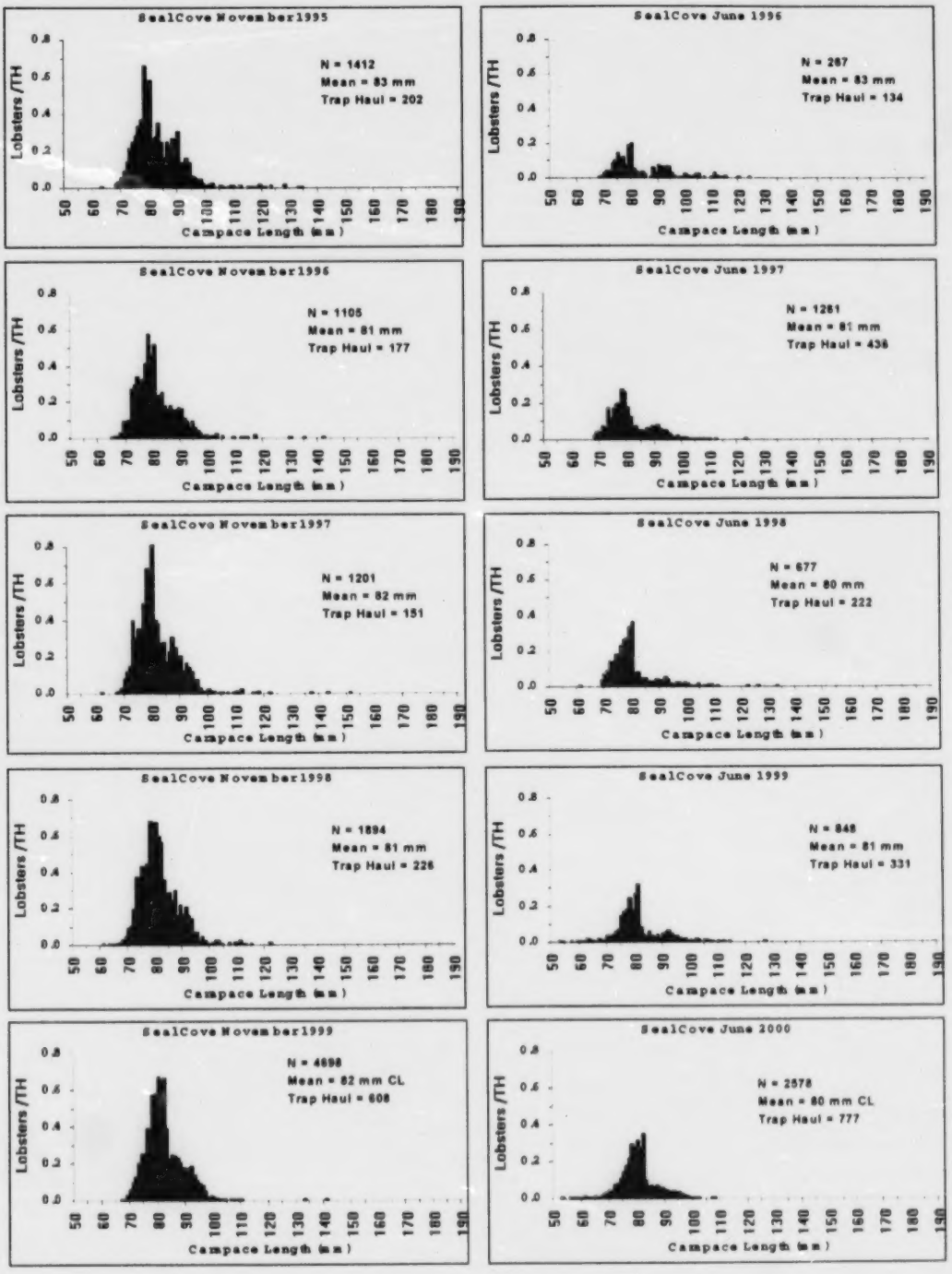


Figure 13. At-sea sampling size frequencies for fishing seasons 1990/91 to 1994/95 for Dipper Harbour (LFA 36).

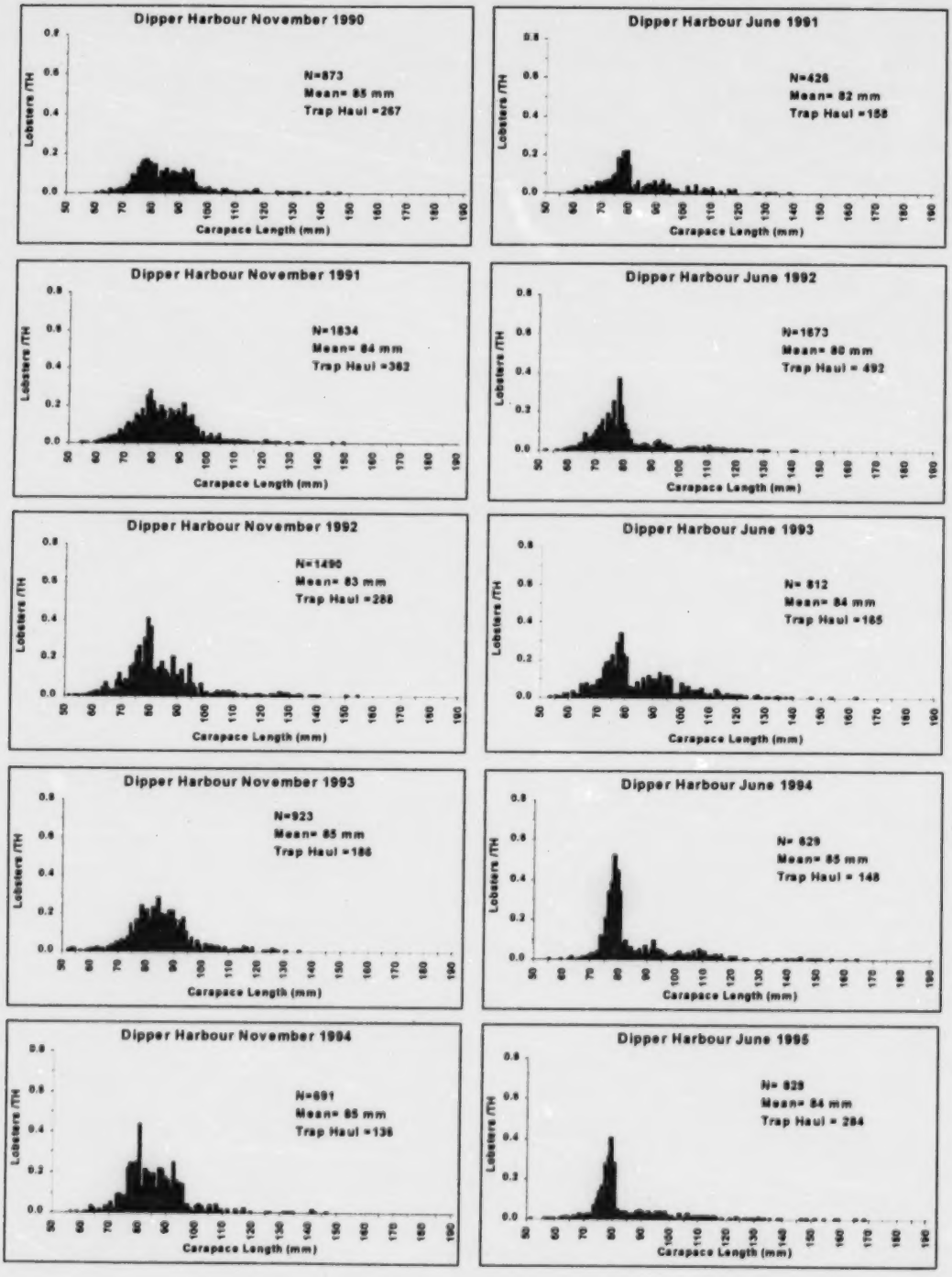


Figure 13 (cont.). At-sea sampling size frequencies for fishing seasons 1995/96 to 1999/2000 for Dipper Harbour (LFA 36).

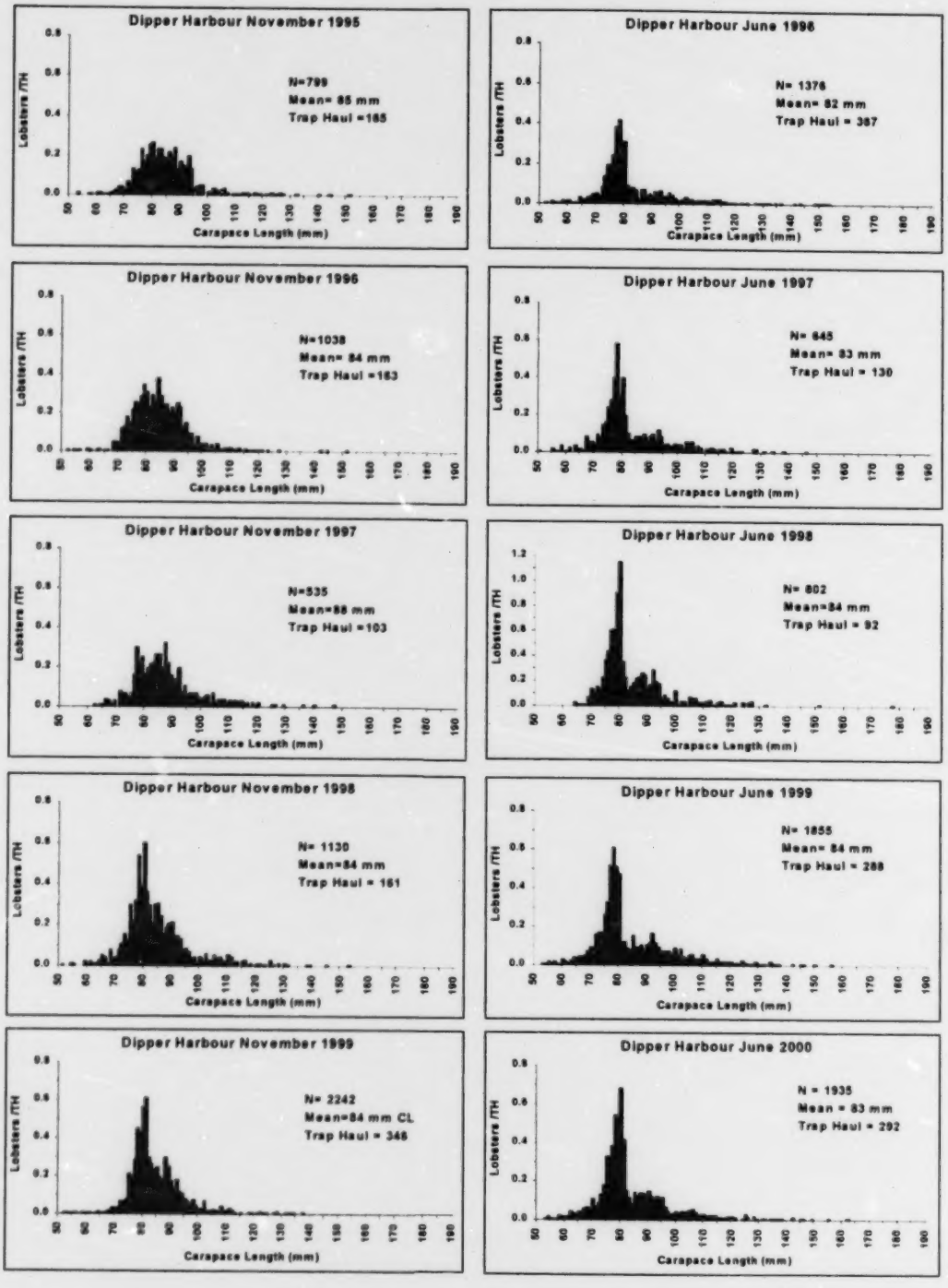


Figure 14. At-sea sampling size frequencies for fishing seasons 1990/91 to 1994/95 for Alma (LFA 35).

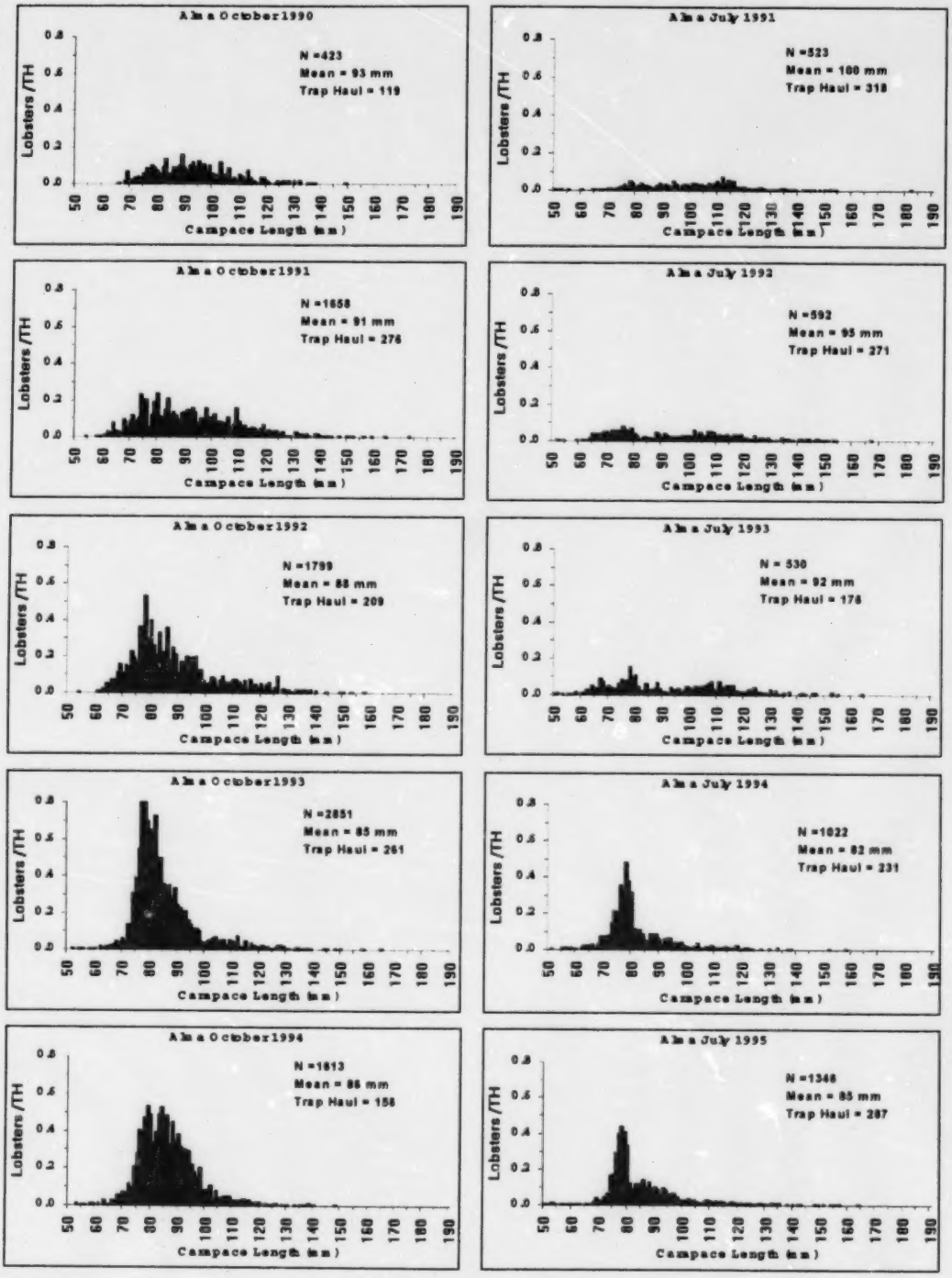


Figure 14 (cont.). At-sea sampling size frequencies for fishing seasons 1995/96 to 1999/2000 for Alma (LFA 35).

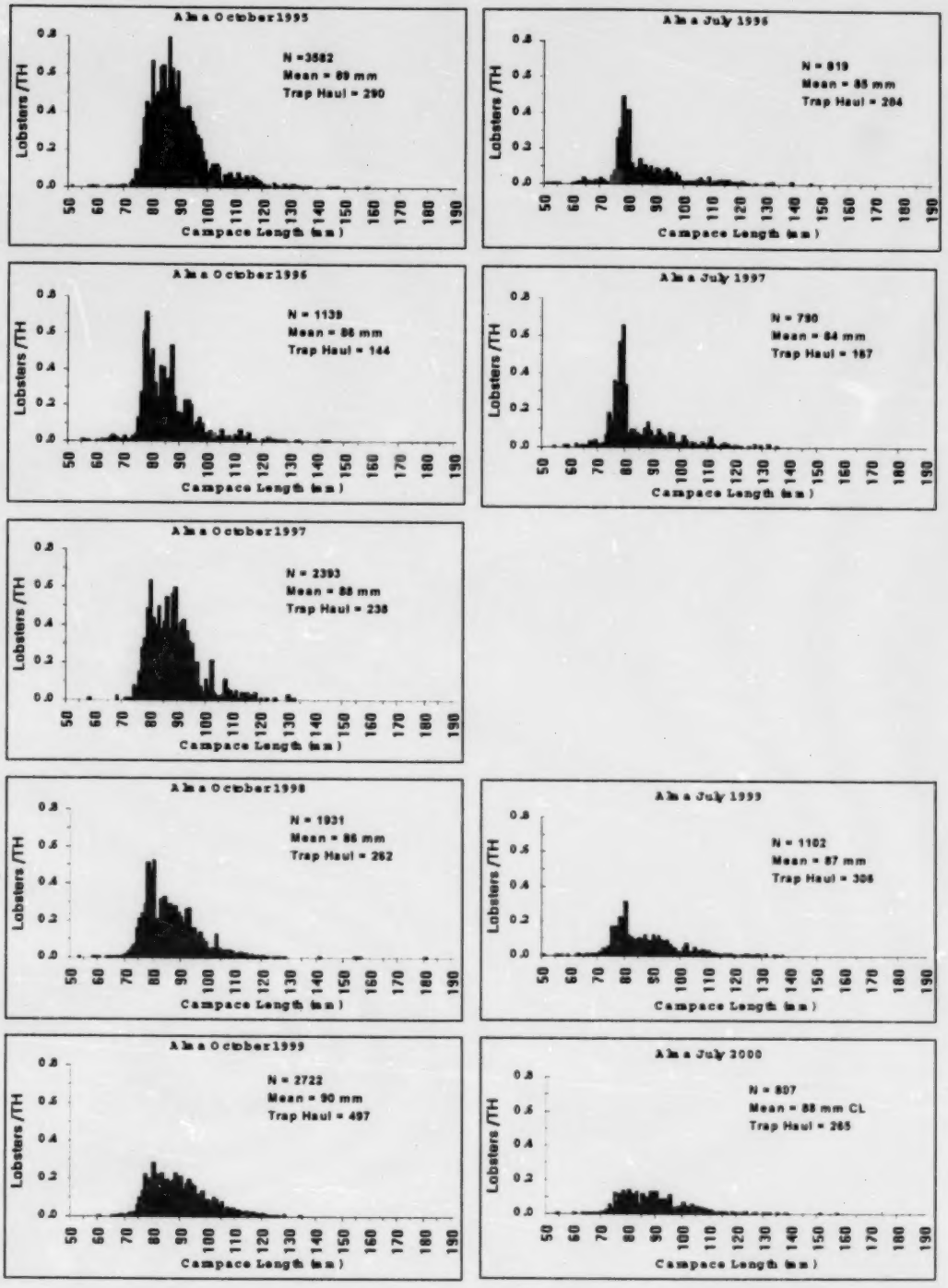
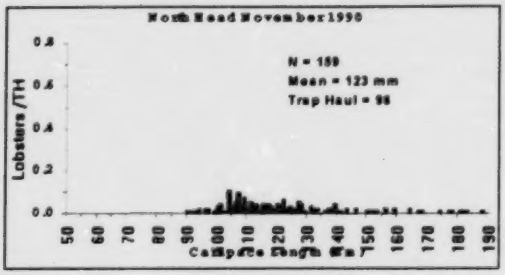
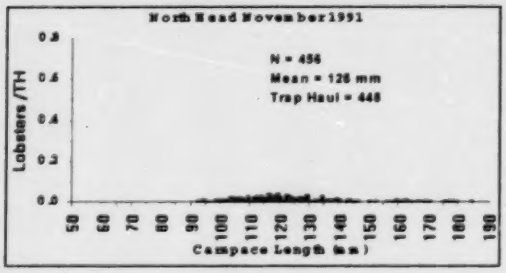
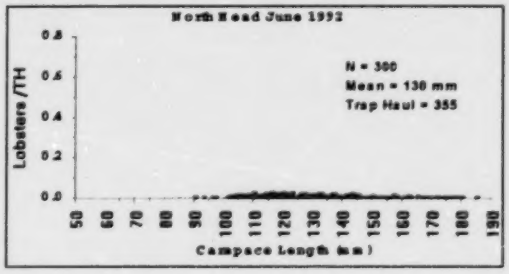
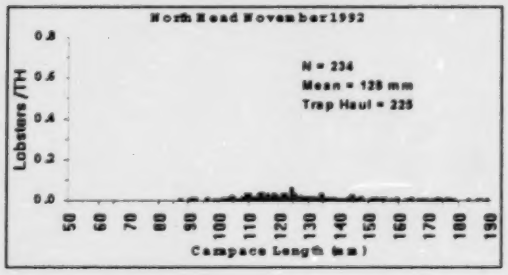


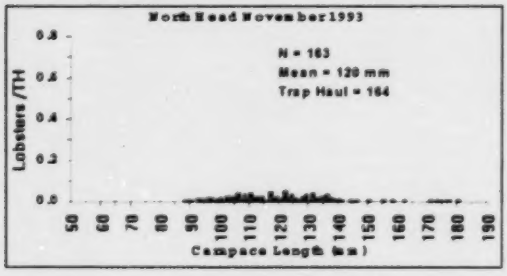
Figure 15. At-sea sampling size frequencies for fishing seasons 1990/91 to 1994/95 for North Head (LFA 38).











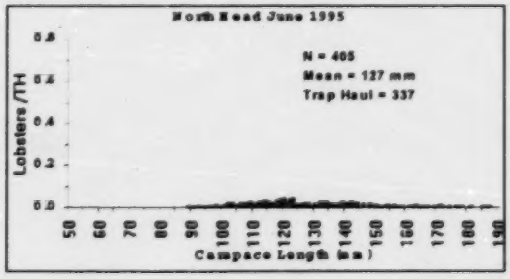


Figure 15 (cont.). At-sea sampling size frequencies for fishing seasons 1995/96 to 1999/2000 for North Head (LFA 38).

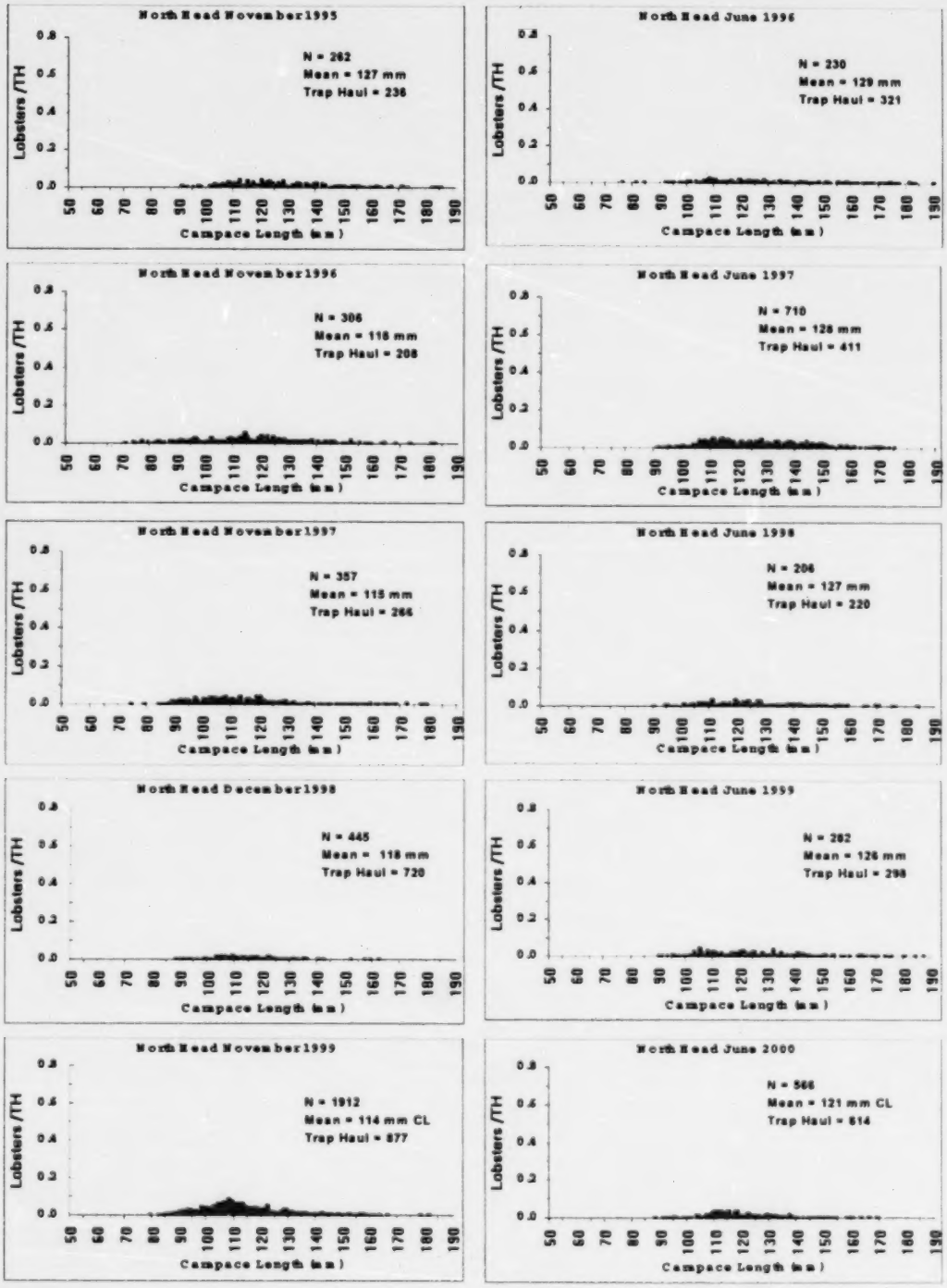


Figure 16. Fall 2000 fishing season at-sea sampling distributions.

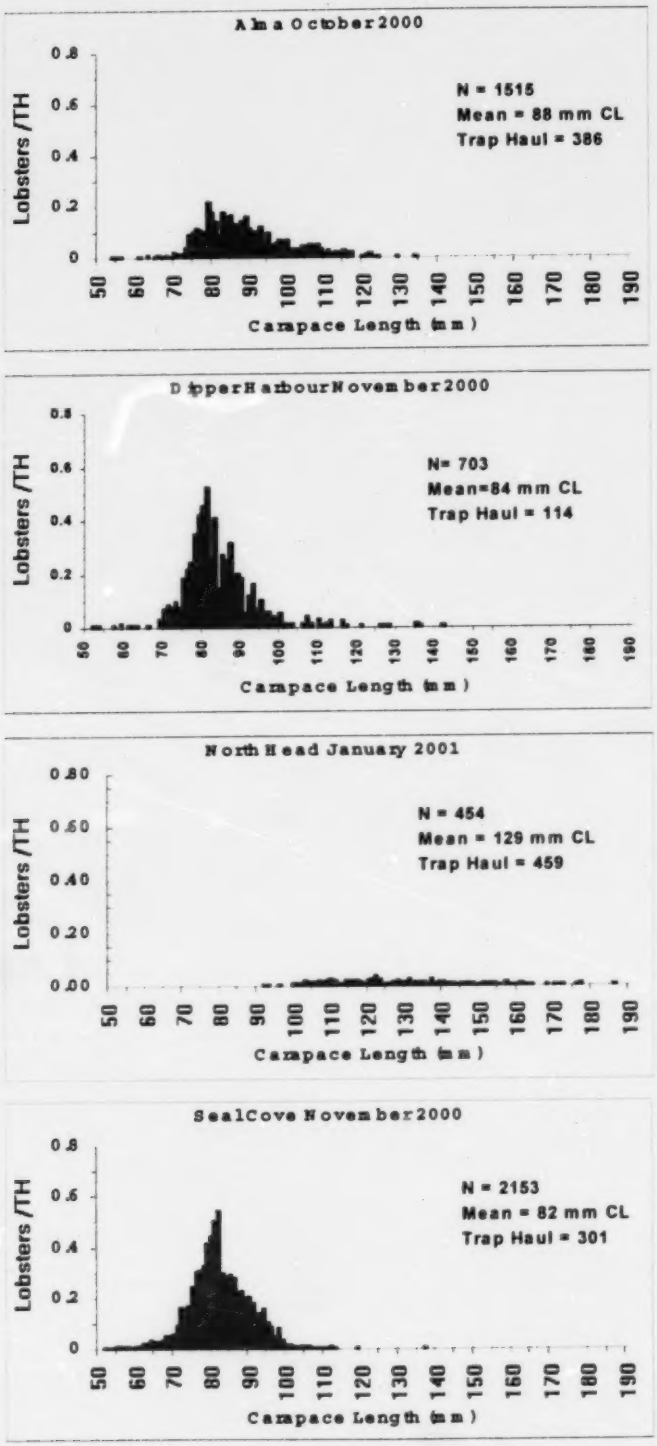


Figure 17. Trends in catch per unit of effort observed in at-sea sampling of lobster catches in four areas of the Bay of Fundy 1978-2000. Number of lobsters per trap haul by moult group.

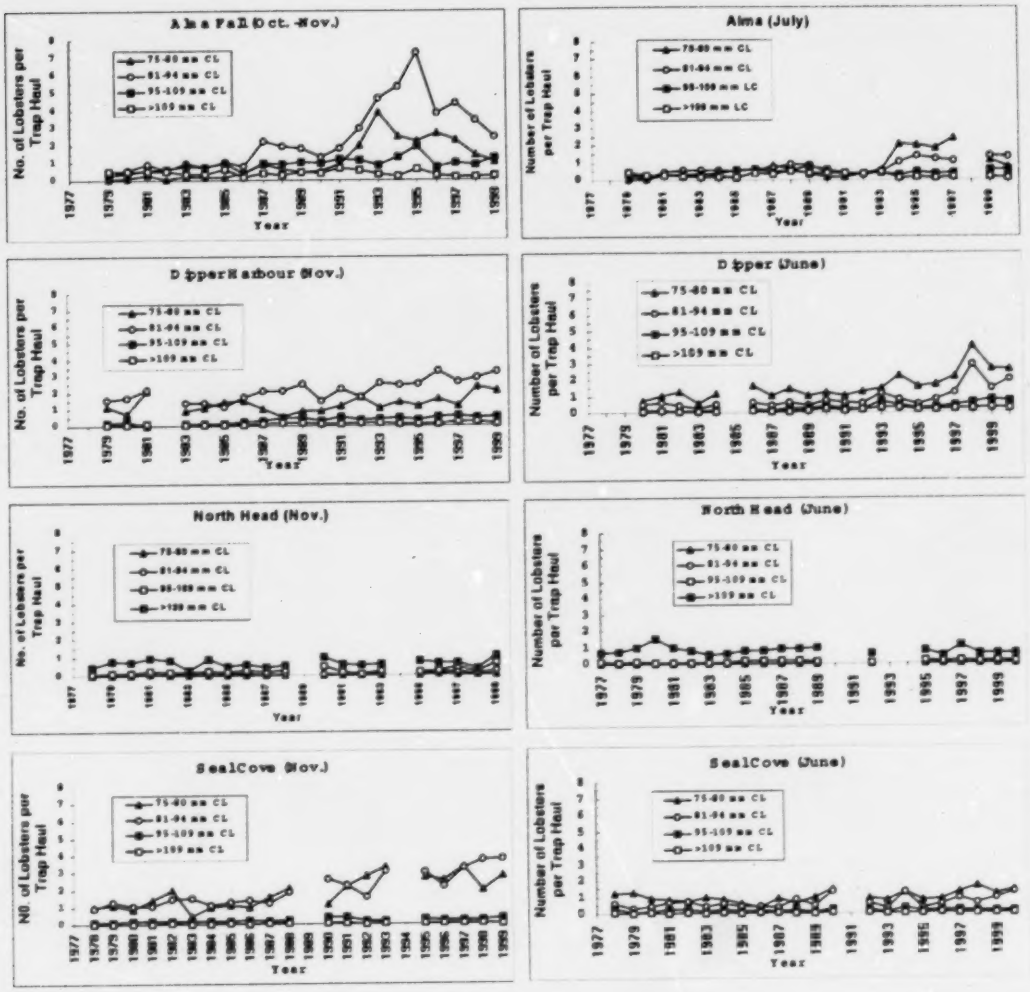


Figure 18. Trends in catch per unit of effort observed in at-sea sampling of lobster catches in four areas of the Bay of Fundy 1978-2000. Kg. of lobsters per trap haul.

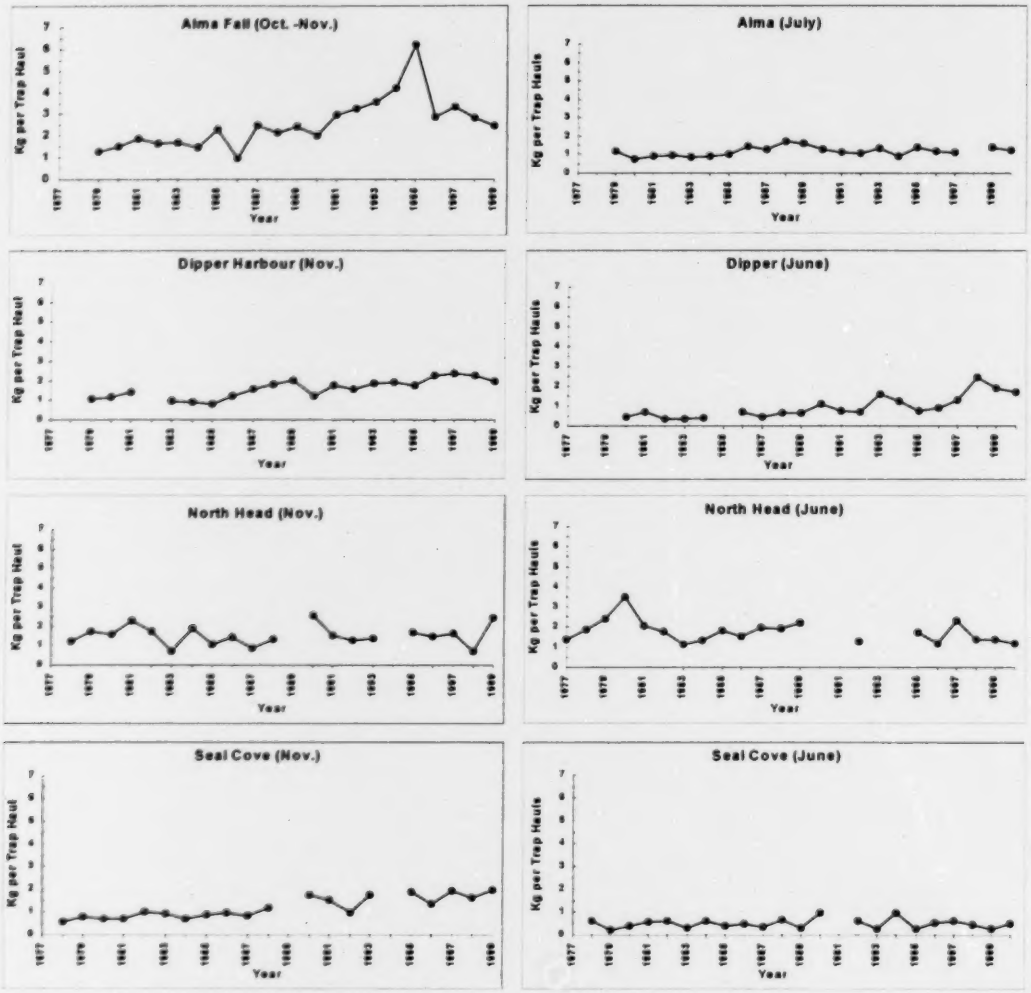


Figure 19. Cumulative frequency distribution of berried female lobsters sampled at-sea in the Bay of Fundy between 1978 and 2000, grouped by 5 year time-period (except most recent period). Sample sizes and sample distribution information in Table 4.

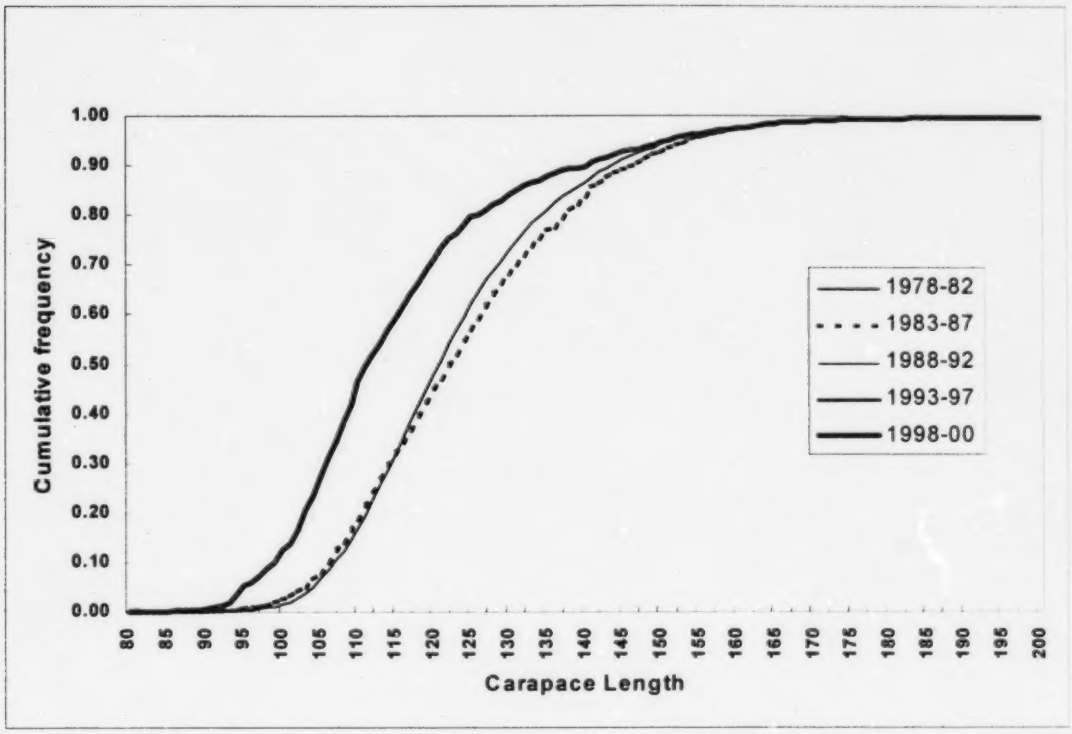


Figure 20. Lobster size distribution from Fisher-supplied at-sea samples in the Minas Basin and off Advocate Harbour (LFA 35), 1997 to 2000, in comparison to DFO Science sampling.

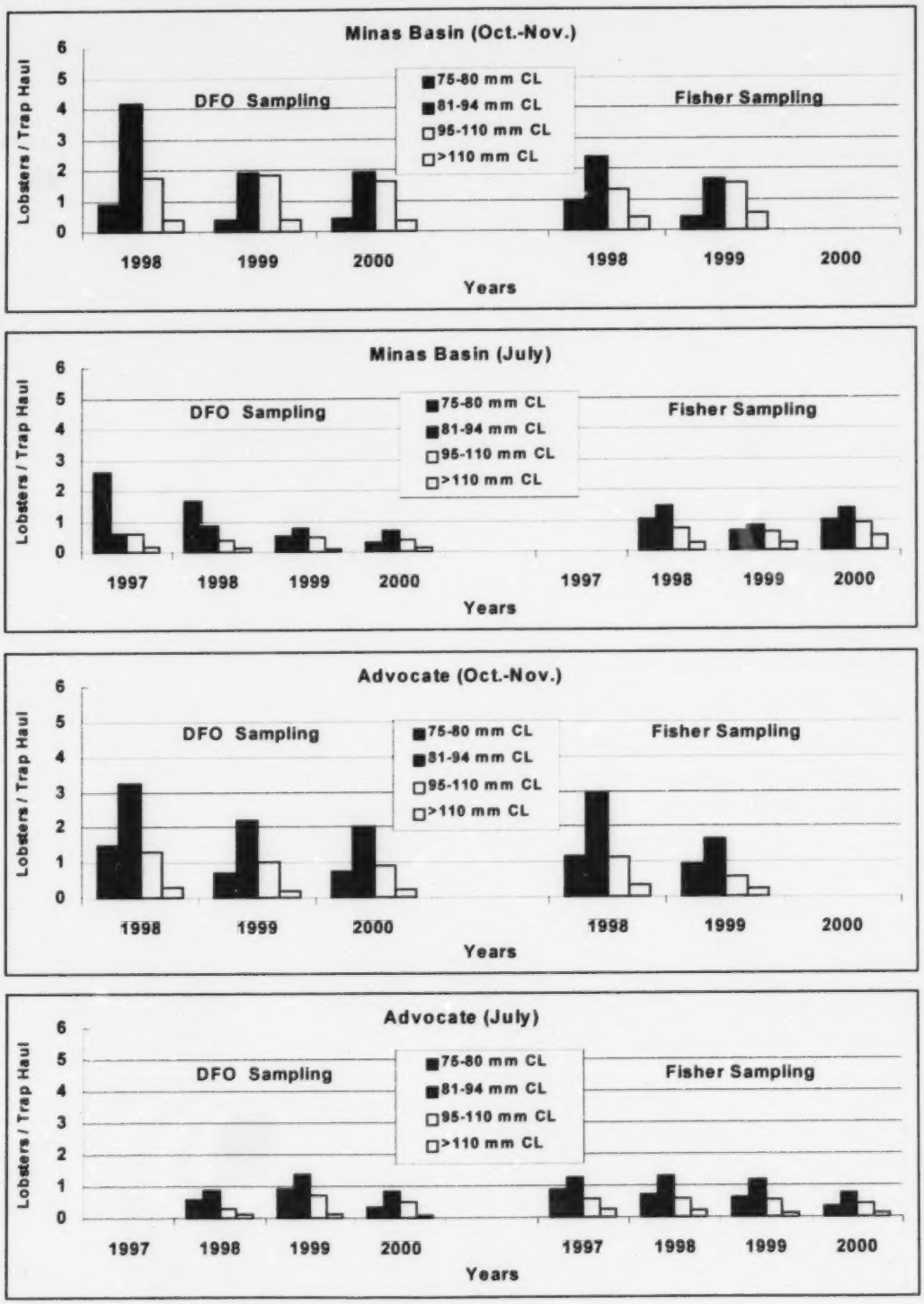
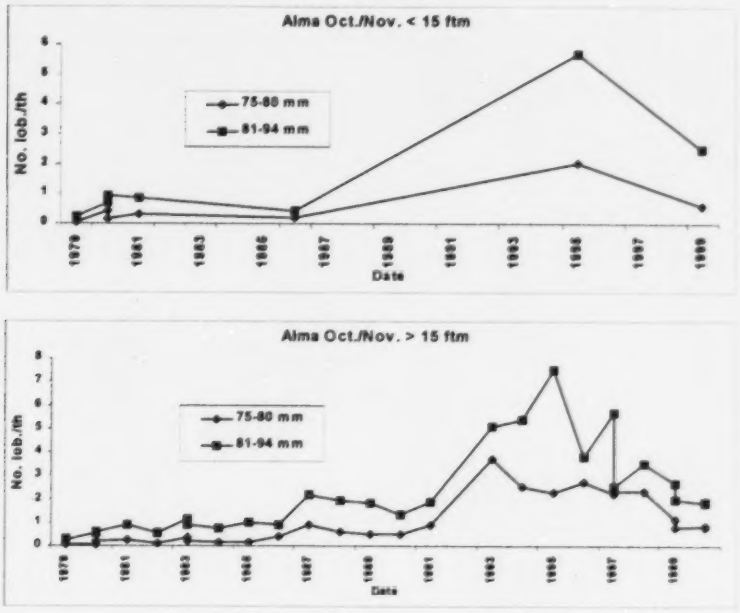


Figure 21. Catch rates of 75-80mm CL and 81-94mm CL lobsters in DFO sea-sampling off Alma, 1979-2000, by depth category, for samples with 20 or more trap hauls per depth category.

(A) At-sea sampling in Fall fishery.



(B) At-sea sampling in Spring fishery.

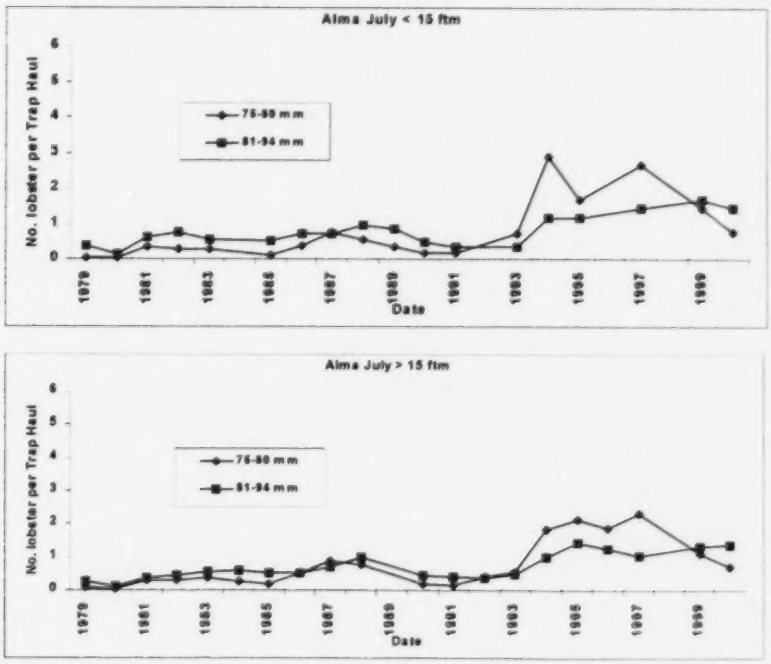
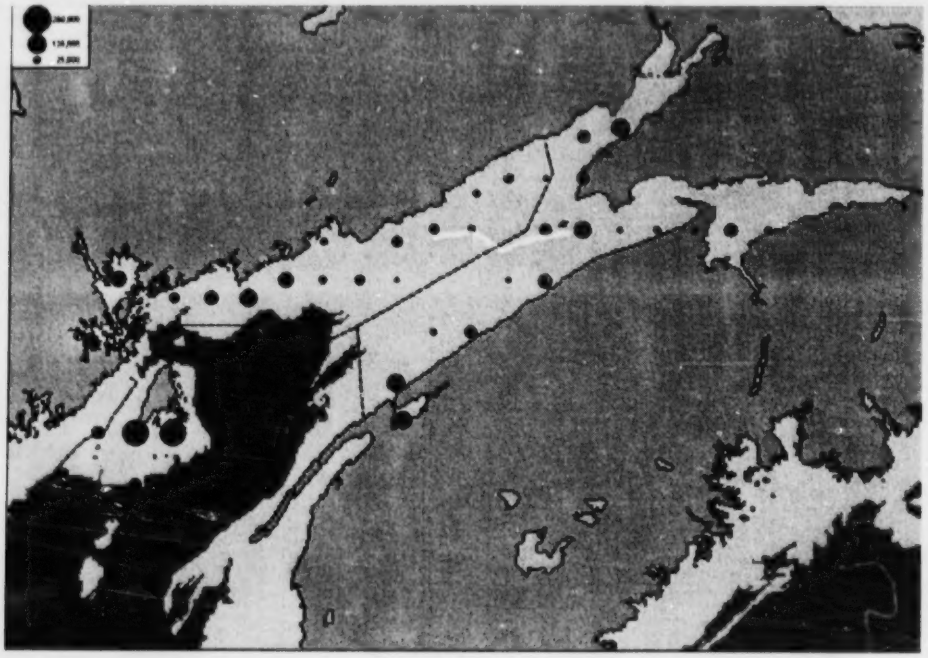


Figure 22. Distribution of lobster landings from the Bay of Fundy for the 1998/99 fishing season by 10 min grid square.

(A) Moult Group 1 (81-94 mm CL; Except where minimum size increased – see text for details).



(B) Moult Group 2 (95-109 mm CL).

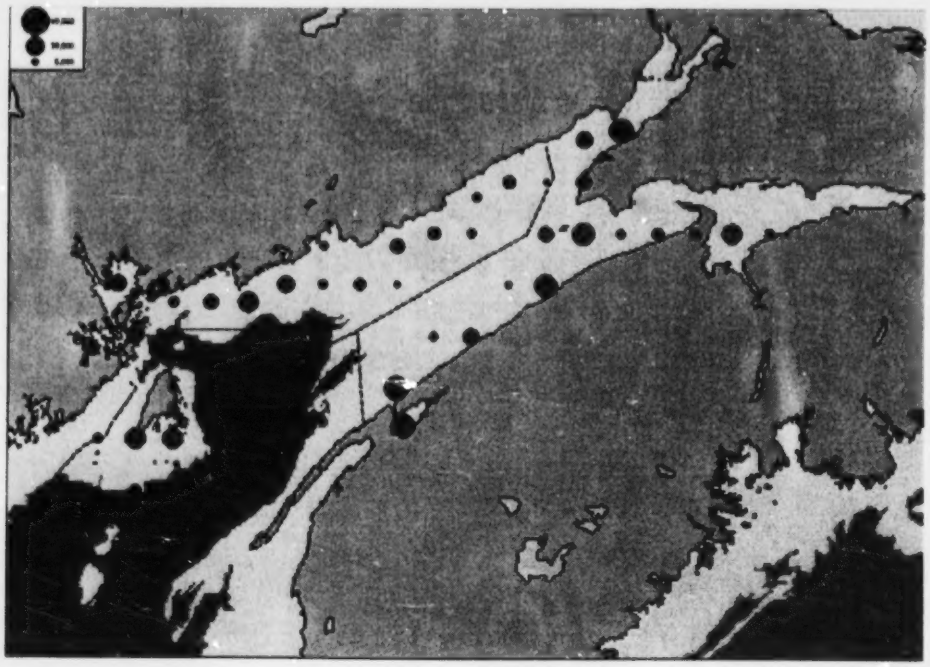


Figure 22 (cont.). Distribution of lobster landings from the Bay of Fundy for the 1998/99 fishing season.

(C) Moult Group 3 and Greater (lobsters 110mm CL and greater).

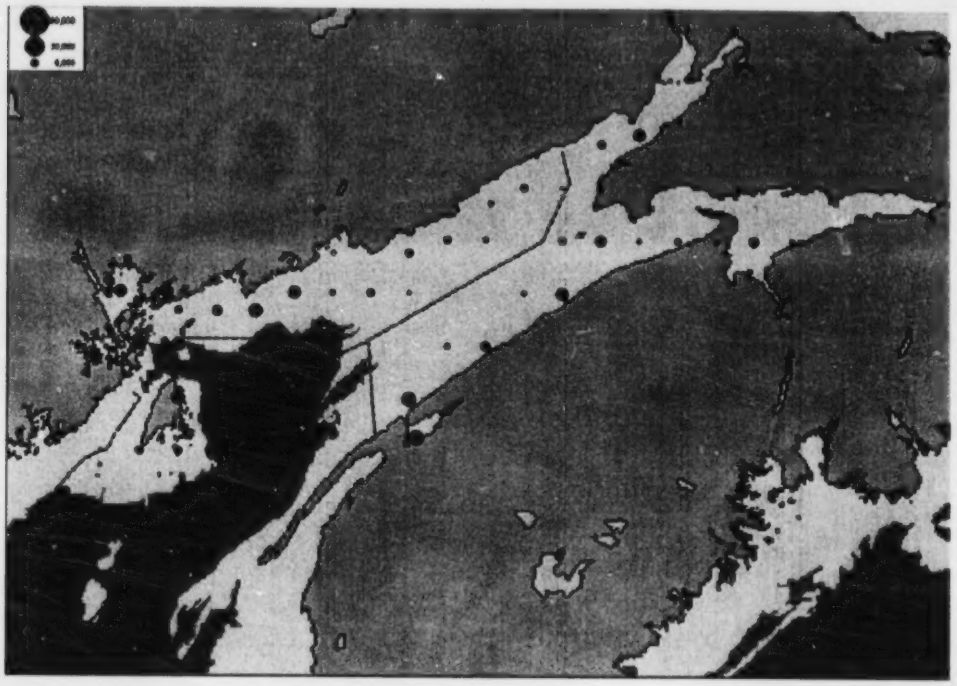
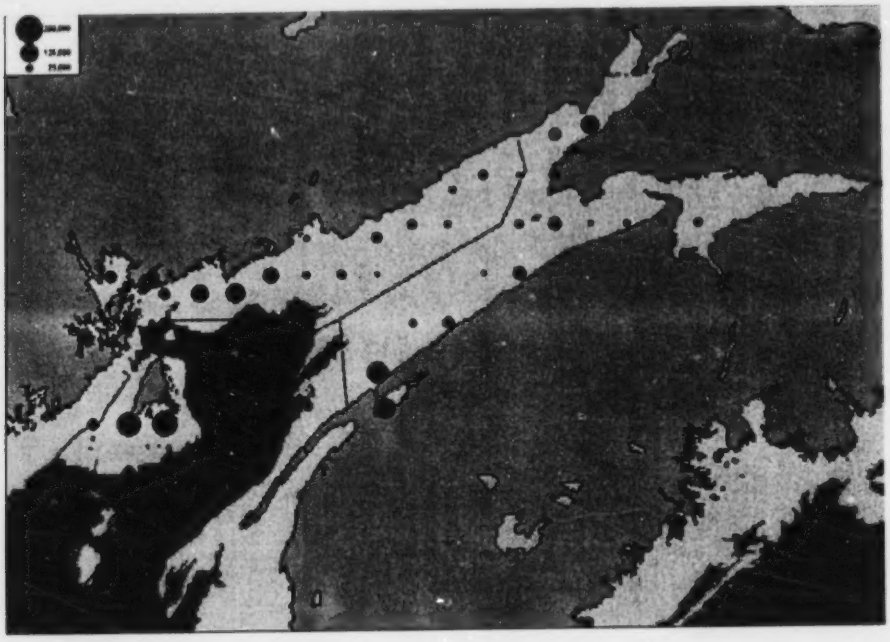


Figure 23. Distribution of lobster landings from the Bay of Fundy for the 1999/00 fishing season.

(A) Moult Group 1 (81-94 mm CL; except where minimum sizes increased – see text).



(B) Moult Group 2 (95-109 mm CL).

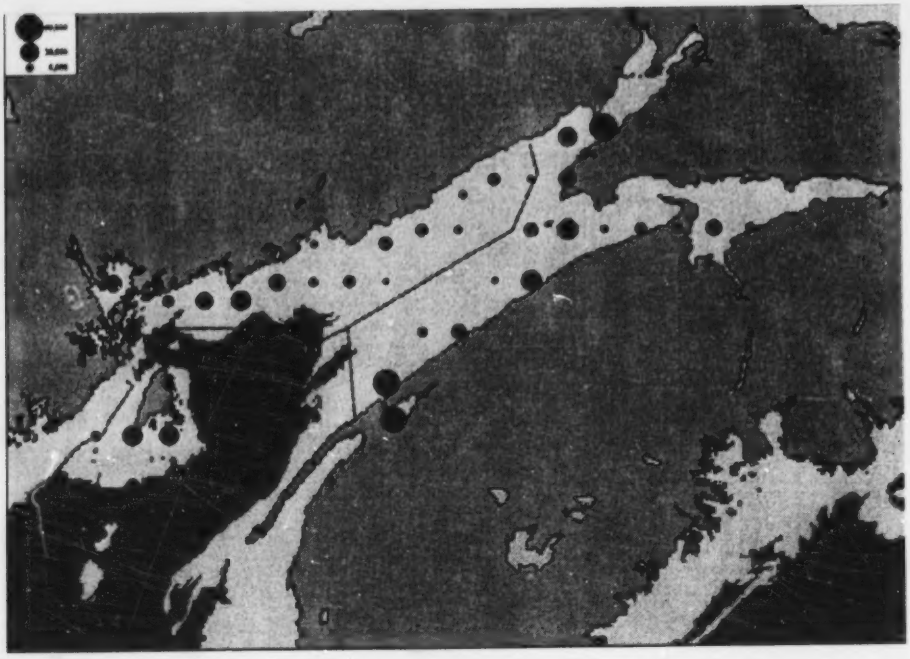


Figure 23 (cont.). Distribution of lobster landings from the Bay of Fundy for the 1999/00 fishing season.

(C) Moult Group 3 and Greater (lobsters 110mm CL and greater).

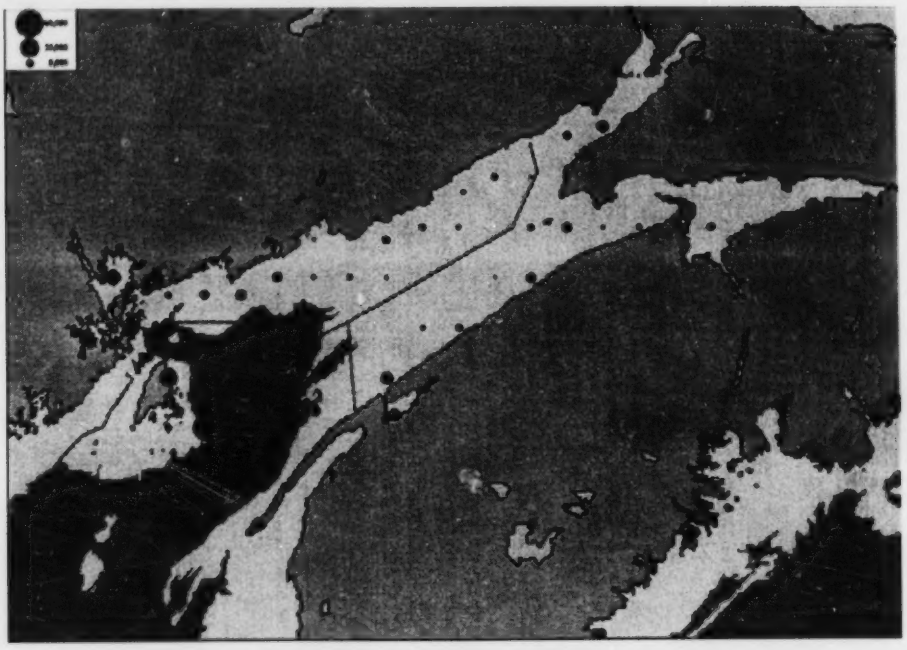


Figure 24. Catch composition – LFA 35 1998/99 fishing season.

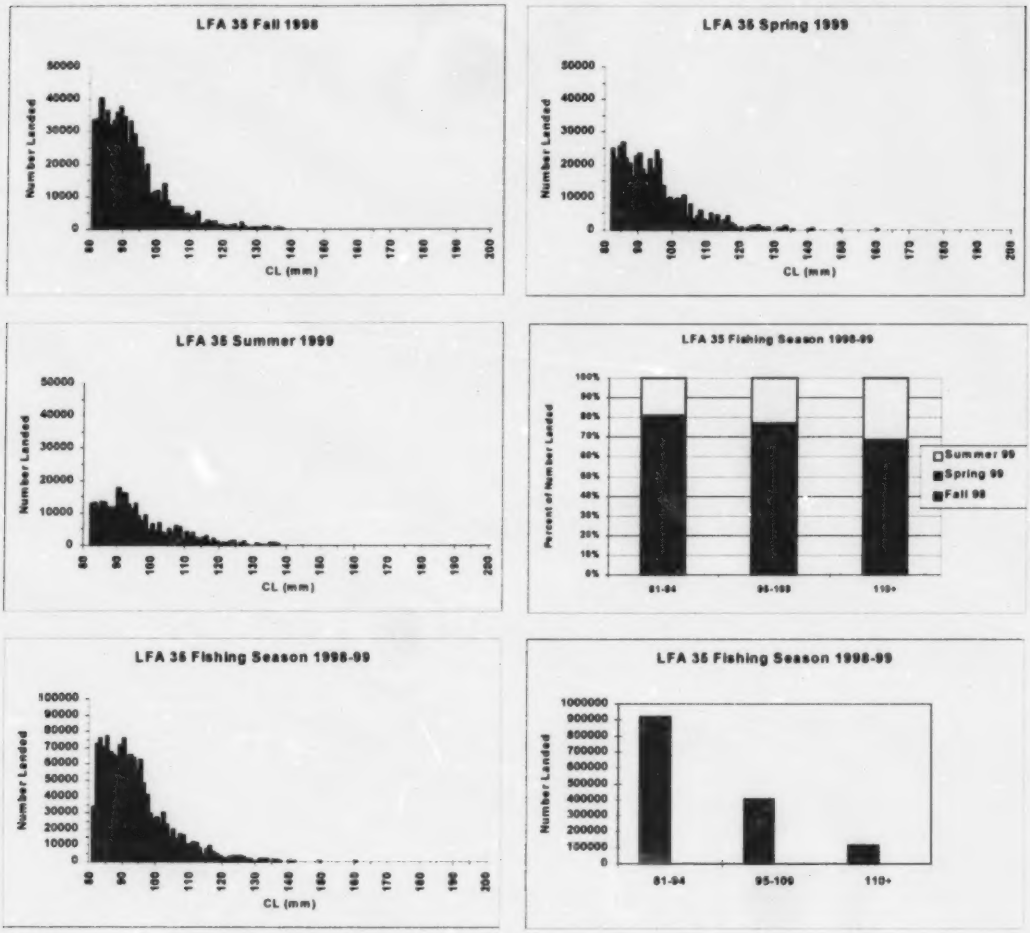
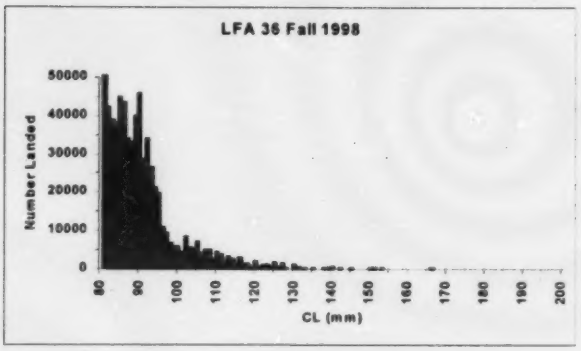
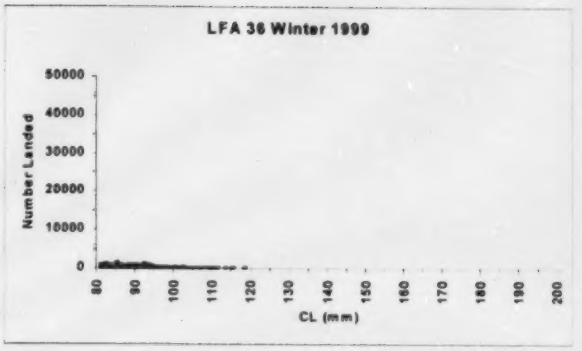
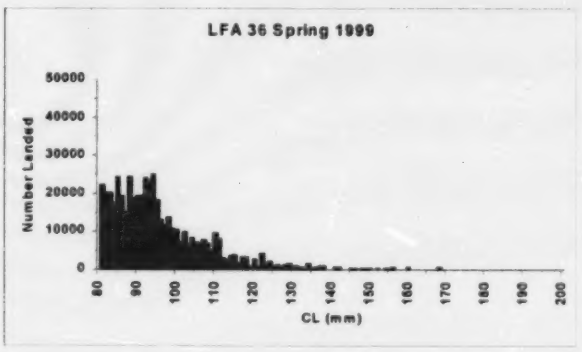
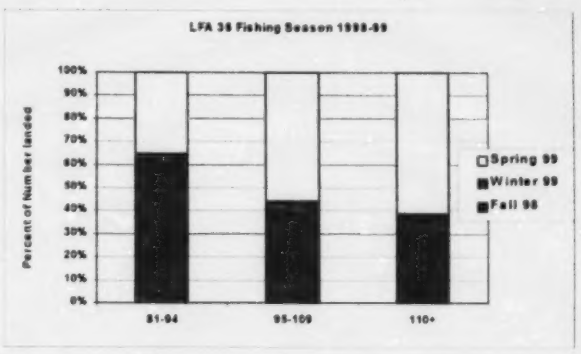


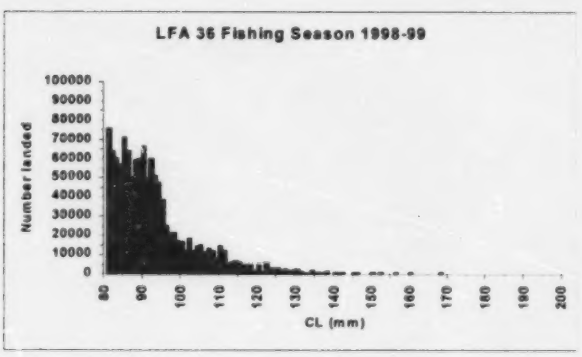
Figure 25. Catch composition – LFA 36 Fishing Season 1998-99.











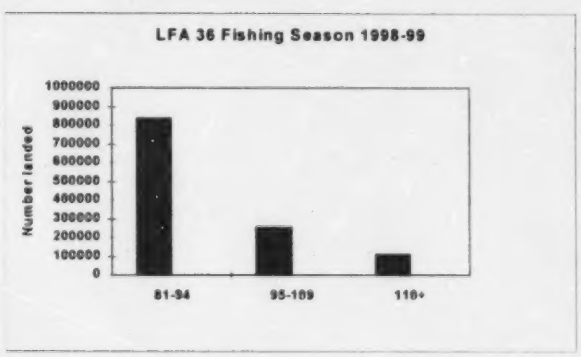
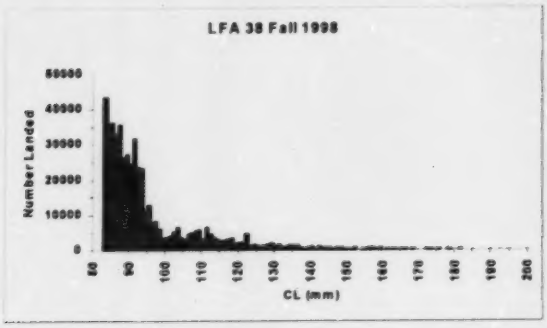
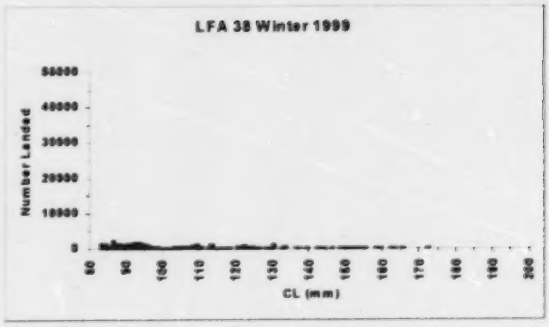
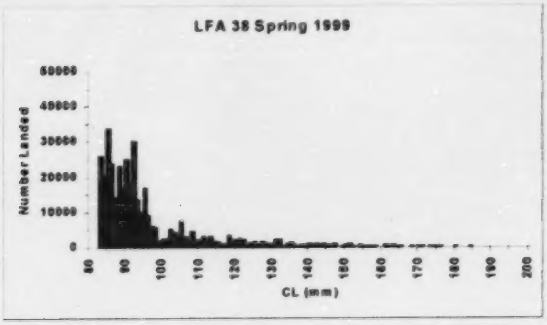
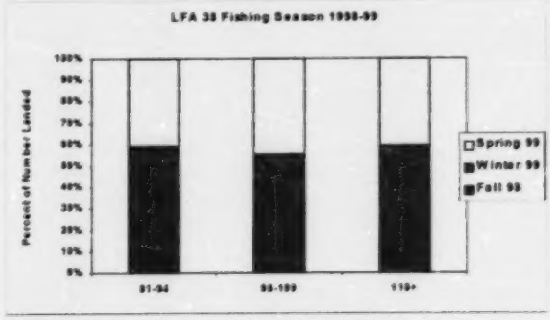


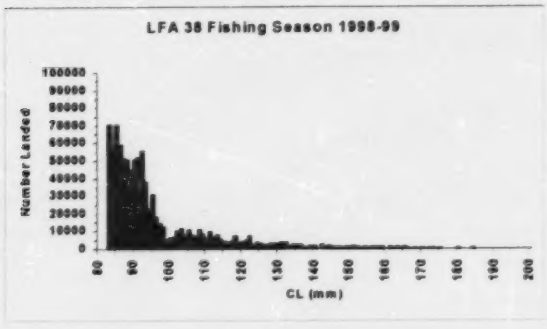
Figure 26. Catch composition – LFA 38 Fishing season 1998-99.











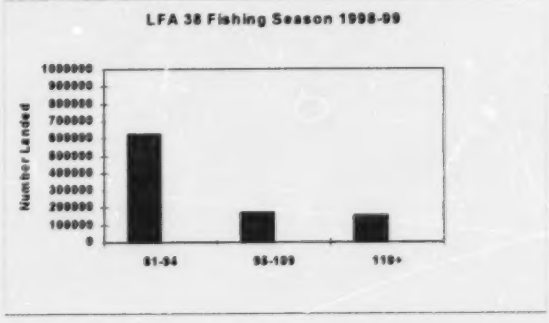
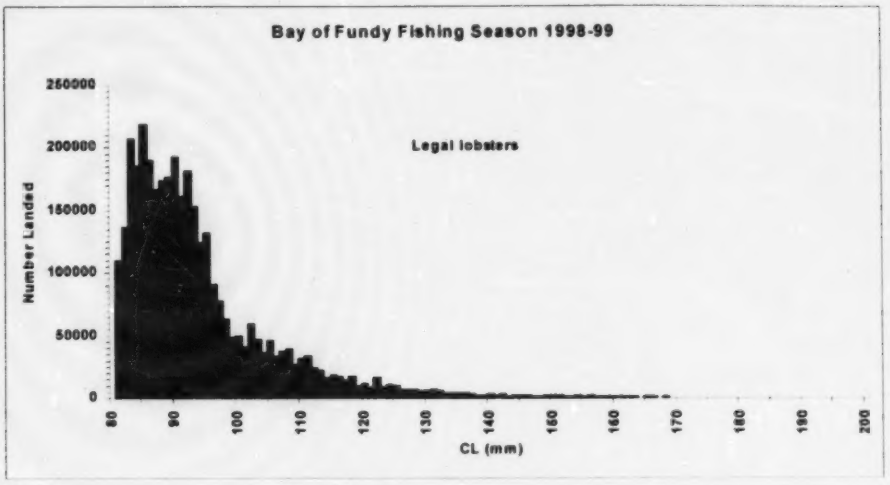
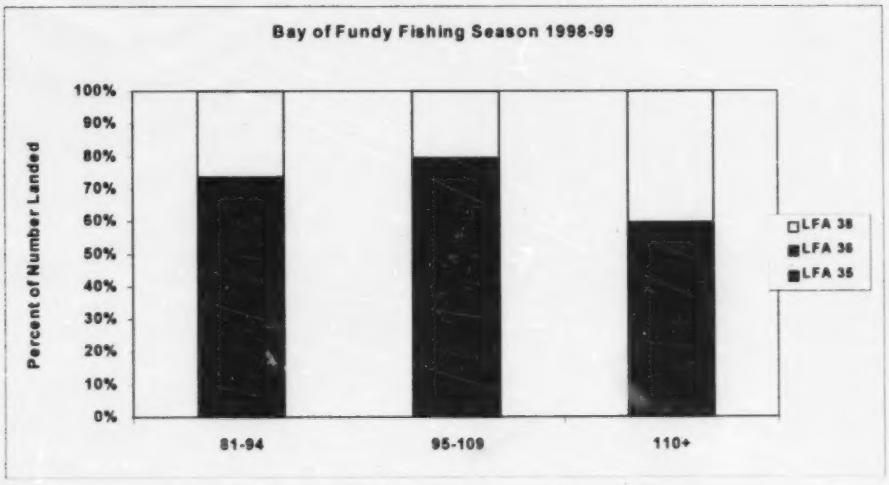


Figure 27. Composite size structure for Bay of Fundy, 1998-99 fishing season.





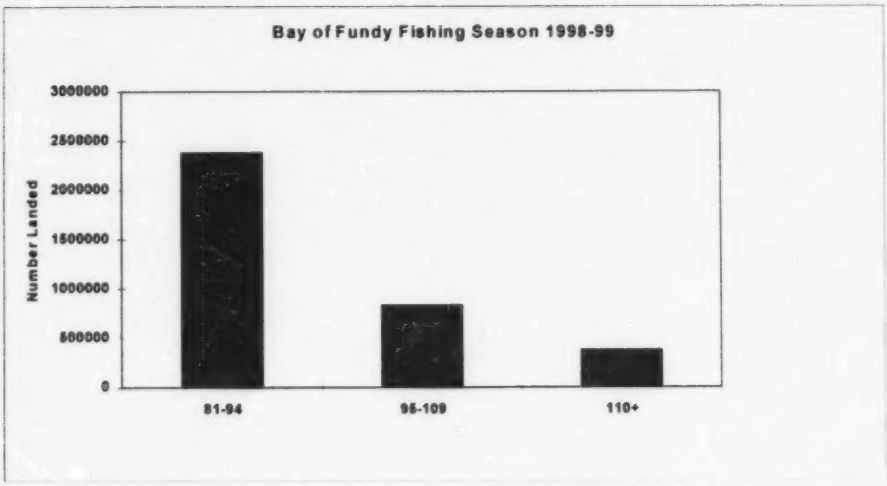


Figure 28. Catch composition – LFA 35 1999/00 fishing season.

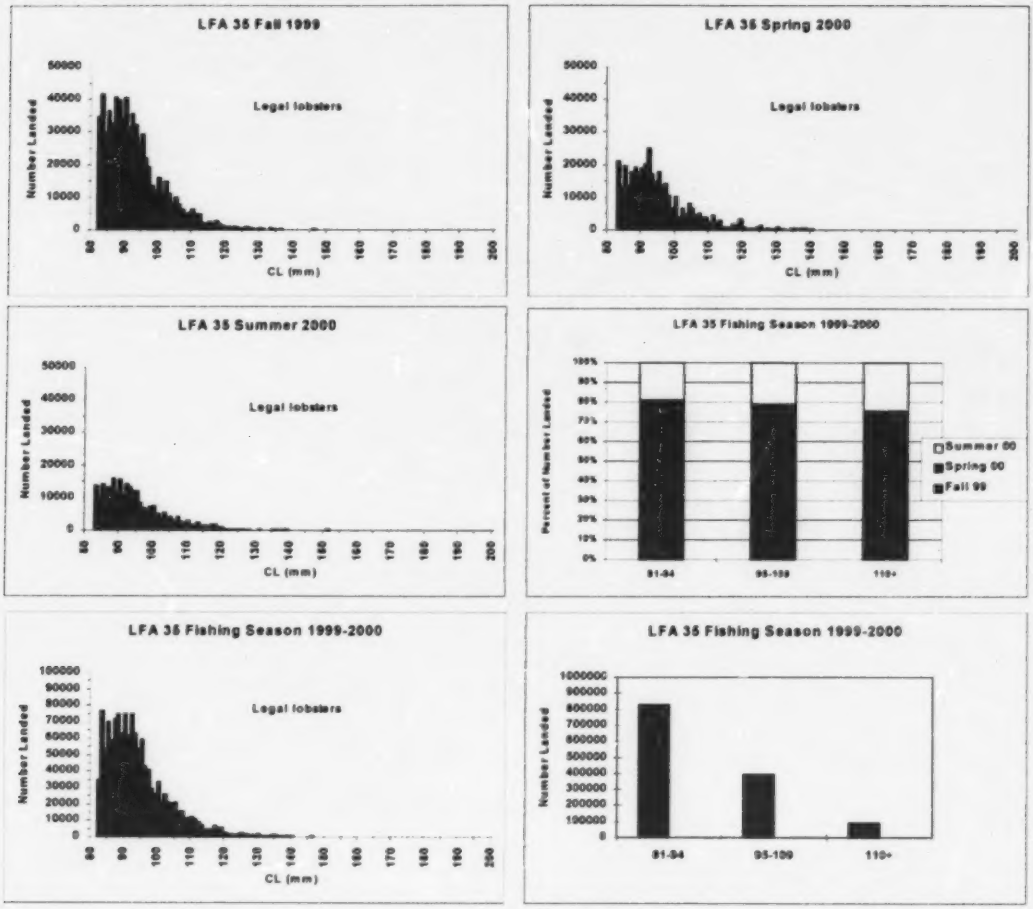


Figure 29. Catch composition – LFA 36 1999/00 fishing season.

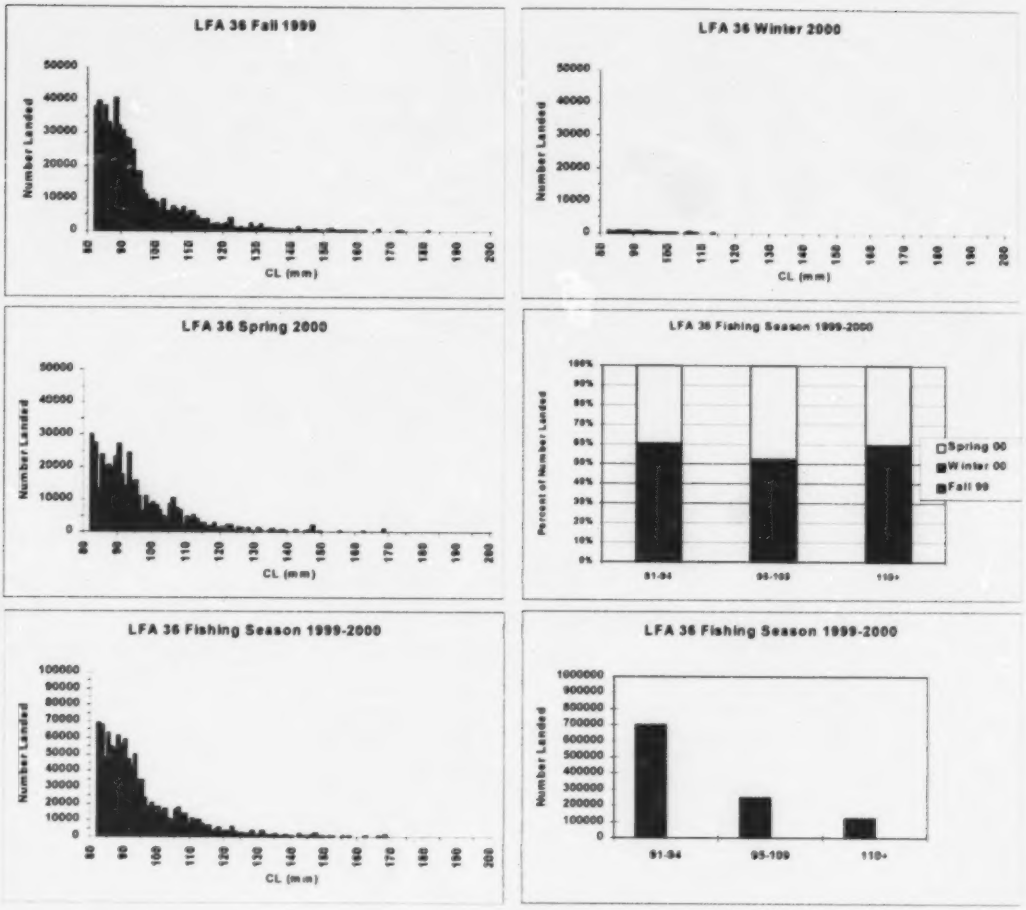


Figure 30. Catch composition – LFA 38 1999/00 fishing season.

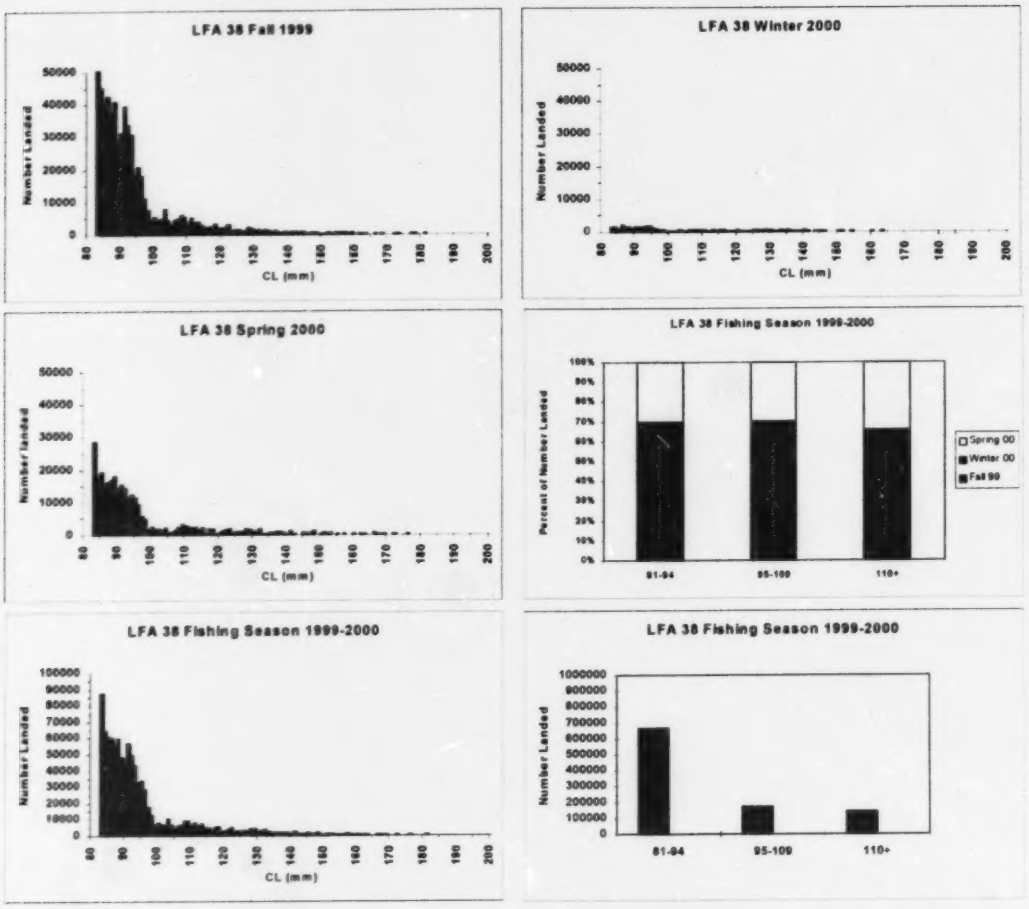
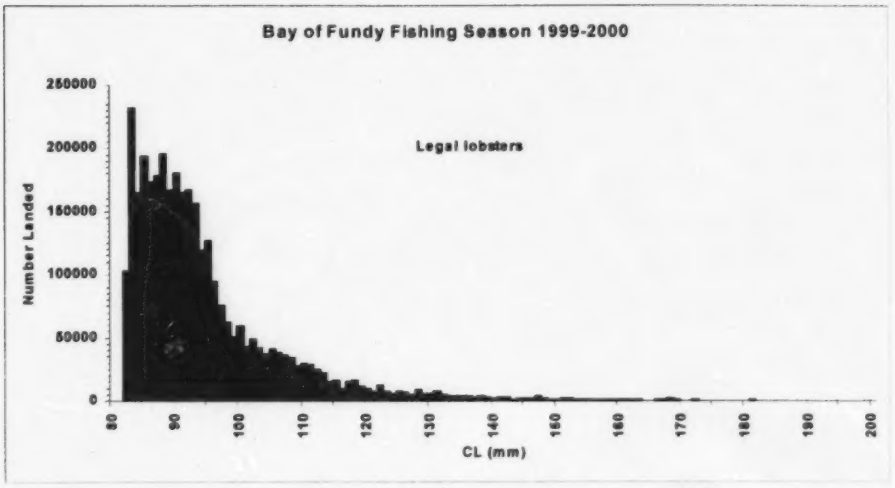
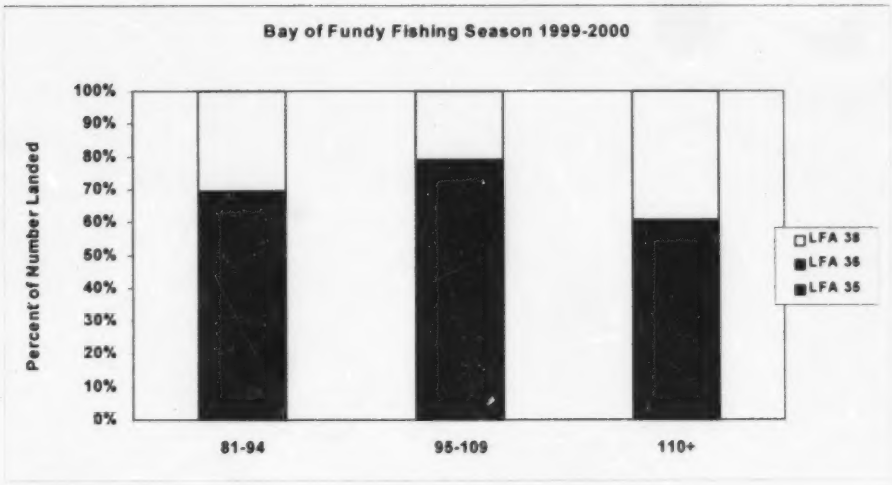
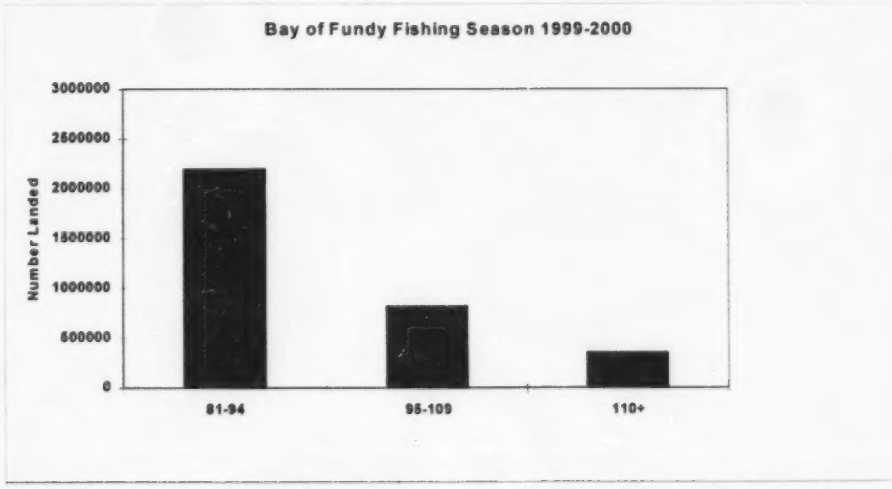


Figure 31. Composite size structure for Bay of Fundy, 1999/00 fishing season.







Appendix 1. Recent conservation management discussions and relevant science/management activities in the Bay of Fundy lobster fishery (a historical review of management policies from late 1800's to 1986 was presented in Lawton et al 1999).

1992: Review of a fishing season extension request by LFA 36 (Lawton and Robichaud, 1992a)

1995: Review of Atlantic lobster fishery by Fisheries Resource Conservation Council (FRCC, 1995).

Change in method of reporting lobster landings from monthly sales slips collected from lobster buyers to a monthly catch settlement report sent in by each fisherman. New program in effect at the start of the Fall 1995 fishery.

1997: Minister of Fisheries and Oceans issues a directive in December 1997 for Atlantic lobster fishers to set in place a 4-year conservation plan to achieve a doubling of egg production per recruit.

1998: Review of status of Bay of Fundy lobster fishery, July 1998 (Lawton et al 1999)

Public release of 4-year conservation plan with a default set of measures to be introduced including increases in minimum size, introduction of a maximum size on females, and a voluntary v-notching program in LFA 36

Minimum legal size increased to 82.5 mm CL prior to the opening of the fishing season in November in LFA 38

1999: Minimum legal size increased to 81.8 mm CL in LFA 35 for the Spring season

LFA 36 increased to a minimum size of 81.8 mm CL for the Fall season. V-notching of berried females was introduced in LFA 36.

2000: Minimum legal size was increased to 82.5 mm CL in LFA 35 for the Spring season and in LFA 36 for the Fall season. By Fall fishery, 2000, LFA's 35, 36 & 38 have same minimum legal size of 82.5 mm CL.

Introduction of a maximum size regulation in LFA's 35, 36, and 38 put on hold following consultations with industry. Prohibition on retention of v-notched lobsters to be introduced in LFA's 35 and 38 in 2001.

Appendix 1 (cont.). Recent conservation management discussions and relevant science/management activities in the Bay of Fundy lobster fishery

Maximum size as a conservation tool:

There has been considerable debate with Industry on the merits of maximum size. There is a degree of scientific uncertainty on final realized benefits of a maximum size regulation in the Gulf of Maine context:

1. Unlike other Canadian areas where the maximum size has been introduced, the Gulf of Maine has large numbers of larger lobsters that are targeted by specific sectors of the fleet or ports. In other areas, numbers are much lower and more evenly spread amongst fishers. Particularly in the Bay of Fundy, these large animals are subject to long distance migrations, making them susceptible to sectors of the commercial fishery across several LFA's.

2. The default plans proposed the introduction of a maximum size in the Bay of Fundy LFA's in 2001. The schedule for adjacent LFA's (LFA 34 in particular) was different, raising the potential problem of a range of maximum size measures in place at one time.

3. A maximum size regulation would impose a disproportionate cost on a small sector of the overall fleet, contravening the principles in the FRCC report on achieving consistency in the application of conservation measures.

4. The initial assessment of a maximum size regulation did not consider the unequal distribution of larger sizes and the potential redeployment of deepwater effort, such as that exercised by a significant sector of the Grand Manan fleet, back into inshore areas.

5. Until there is uniform regulation throughout Canadian, US state, and US federal waters in the Gulf of Maine, introduction of a maximum size regulation in the Canadian fishery would not offer full protection to large lobsters which migrate throughout the region and this needs to be calculated into the assessment.

V-notching as a conservation tool:

1. DFO Science has categorized v-notching as a problematic conservation approach, due to the problems of evaluating compliance, reliance on continued high levels of voluntary participation by fishers for full effectiveness, and potential disease/incidental mortality considerations. None of these factors are of themselves criteria on which to preclude v-notching as a principal conservation plan element, but rather they are factors that require ongoing evaluation.

2. Particularly with respect to evaluation of v-notching in the egg per recruit model there are two issues which affect the projected benefits from a v-notching program:

    - Encounter rate of berried females vs other females
    - Participation rate (% vnotched)

Appendix 2. Summary of at-sea sample data for period Oct 1998-July 2000. The number of legal-sized lobsters (males and females combined) sampled in commercial fisheries sampling within each group is indicated. Sample sizes are generally highest during the first and last months of each Fall-Spring season.

	1998/1999 (Total Legals)							1999/2000 (Total Legals)								
GROUPNO	Oct.	Nov.	Dec.	Jan.	May	June	July	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July
1	2438				229	361	956	3379	672						268	245	521
2	128					186	180	734	294							111	139
3	233					99	374	452	230							283	589
4	526					287	247	1089	504							342	1167
5			225			788			1164	108						911	
6		711				713			1403							216	
7		391				186			1010	208						120	
8			373	92	211	239			1515	599		157	191	80		479	
9		771			85	319			2303	705	111		146	314	581	1125	
10						52				104	231				225	113	

Appendix 3: Allocation of landings within Statistical Districts in the Bay of Fundy. The same allocation was used for each fishing season.

STD	Grid#	Total %	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July
53	26	20%	0%	20%	20%	20%	0%	0%	20%	20%	20%	0%
	27	40%	0%	40%	40%	40%	0%	0%	40%	40%	40%	0%
	39	25%	0%	25%	25%	25%	0%	0%	25%	25%	25%	0%
	28	15%	0%	15%	15%	15%	0%	0%	15%	15%	15%	0%
52	25	100%	0%	100%	100%	100%	0%	0%	100%	100%	100%	0%
51	38	50%	0%		50%	50%	0%	0%	50%	50%	50%	0%
	39	35%	0%	35%	35%	35%	0%	0%	35%	35%	35%	0%
	25	15%	0%	15%	15%	15%	0%	0%	15%	15%	15%	0%
50	50	8%	0%	8%	8%	8%	8%	8%	8%	8%	8%	0%
	51	6%	0%	6%	6%	6%	6%	6%	6%	6%	6%	0%
	52	2%	0%	2%	2%	3%	3%	3%	2%	2%	2%	0%
	62	5%	0%	5%	5%	3%	3%	3%	5%	5%	5%	0%
	63	20%	0%	20%	20%	3%	3%	3%	20%	20%	20%	0%
	64	20%	0%	20%	20%	10%	10%	10%	20%	20%	20%	0%
	65	15%	0%	15%	15%	35%	35%	35%	15%	15%	15%	0%
	66	6%	0%	6%	6%	15%	15%	15%	6%	6%	6%	0%
	74	1%	0%	1%	1%	0%	0%	0%	1%	1%	1%	0%
	75	2%	0%	2%	2%	5%	5%	5%	2%	2%	2%	0%
	76	9%	0%	9%	9%	3%	3%	3%	9%	9%	9%	0%
	77	3%	0%	3%	3%	6%	6%	6%	3%	3%	3%	0%
	87	2%	0%	2%	2%	2%	2%	2%	2%	2%	2%	0%
	88	1%	0%	1%	1%	1%	1%	1%	1%	1%	1%	0%
49	8	8%	0%	8%	8%	8%	0%	0%	8%	8%	8%	0%
	28	35%	0%	35%	35%	35%	0%	0%	35%	35%	35%	0%
	29	35%	0%	35%	35%	35%	0%	0%	35%	35%	35%	0%
	30	10%	0%	10%	10%	10%	0%	0%	10%	10%	10%	0%
	31	12%	0%	12%	12%	12%	0%	0%	12%	12%	12%	0%
48	9	25%	0%	25%	25%	25%	0%	0%	25%	25%	25%	0%
	10	20%	0%	20%	20%	20%	0%	0%	20%	20%	20%	0%
	11	10%	0%	10%	10%	10%	0%	0%	10%	10%	10%	0%
	4	10%	0%	10%	10%	10%	0%	0%	10%	10%	10%	0%
	5	20%	0%	20%	20%	20%	0%	0%	20%	20%	20%	0%
	6	5%	0%	5%	5%	5%	0%	0%	5%	5%	5%	0%
	32	5%	0%	5%	5%	5%	0%	0%	5%	5%	5%	0%
	31	5%	0%	5%	5%	5%	0%	0%	5%	5%	5%	0%
79	2	35%	35%	35%	35%	0%	0%	35%	35%	35%	35%	35%
	3	45%	45%	45%	45%	0%	0%	45%	45%	45%	45%	45%
	7	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
81	1	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
	2	80%	80%	80%	80%	0%	0%	80%	80%	80%	80%	80%
24	3	80%	80%	80%	80%	0%	0%	80%	80%	80%	80%	80%
	7	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
44	7	5%	5%	5%	5%	0%	0%	5%	5%	5%	5%	5%
	13	25%	25%	25%	25%	0%	0%	25%	25%	25%	25%	25%
	14	45%	45%	45%	45%	0%	0%	45%	45%	45%	45%	45%
	15	3%	3%	3%	3%	0%	0%	3%	3%	3%	3%	3%
	16	1%	1%	1%	1%	0%	0%	1%	1%	1%	1%	1%
	17	1%	1%	1%	1%	0%	0%	1%	1%	1%	1%	1%
	18	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
43	19	100%	100%	100%	100%	0%	0%	100%	100%	100%	100%	100%
41	17	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
	18	80%	80%	80%	80%	0%	0%	80%	80%	80%	80%	80%
40	17	20%	20%	20%	20%	0%	0%	20%	20%	20%	20%	20%
	16	30%	30%	30%	30%	0%	0%	30%	30%	30%	30%	30%
	15	10%	10%	10%	10%	0%	0%	10%	10%	10%	10%	10%
	14	10%	10%	10%	10%	0%	0%	10%	10%	10%	10%	10%
	36	30%	30%	30%	30%	0%	0%	30%	30%	30%	30%	30%
35	36	45%	45%	45%	45%	0%	0%	45%	45%	45%	45%	45%
	47	45%	45%	45%	45%	0%	0%	45%	45%	45%	45%	45%
	35	10%	10%	10%	10%	0%	0%	10%	10%	10%	10%	10%
39	56	55%	55%	55%	55%	0%	0%	55%	55%	55%	55%	55%
	57	35%	35%	35%	35%	0%	0%	35%	35%	35%	35%	35%
	46	10%	10%	10%	10%	0%	0%	10%	10%	10%	10%	10%
38	56	30%	30%	30%	30%	0%	0%	30%	30%	30%	30%	30%
	57	70%	70%	70%	70%	0%	0%	70%	70%	70%	70%	70%

Appendix 3: Allocation of landings within Statistical Districts in the Bay of Fundy. The same allocation was used for each fishing season.

STD	Grid#	Total %	Nov.	Dec.	April	May	June
53	26	20%	20%	20%	20%	20%	20%
	27	40%	40%	40%	40%	40%	40%
	39	25%	25%	25%	25%	25%	25%
	28	15%	15%	15%	15%	15%	15%
52	25	100%	100%	100%	100%	100%	100%
51	38	50%	50%	50%	50%	50%	50%
	39	35%	35%	35%	35%	35%	35%
	25	15%	15%	15%	15%	15%	15%
50	50	8%	8%	8%	8%	8%	8%
	51	6%	6%	6%	6%	6%	6%
	52	2%	2%	2%	2%	2%	2%
	62	5%	5%	5%	5%	5%	5%
	63	20%	20%	20%	20%	20%	20%
	64	20%	20%	20%	20%	20%	20%
	65	15%	15%	15%	15%	15%	15%
	66	6%	6%	6%	6%	6%	6%
	74	1%	1%	1%	1%	1%	1%
	75	2%	2%	2%	2%	2%	2%
	76	9%	9%	9%	9%	9%	9%
	77	3%	3%	3%	3%	3%	3%
	87	2%	2%	2%	2%	2%	2%
	88	1%	1%	1%	1%	1%	1%
49	8	8%	8%	8%	8%	8%	8%
	28	35%	35%	35%	35%	35%	35%
	29	35%	35%	35%	35%	35%	35%
	30	10%	10%	10%	10%	10%	10%
	31	12%	12%	12%	12%	12%	12%
48	9	25%	25%	25%	25%	25%	25%
	10	20%	20%	20%	20%	20%	20%
	11	10%	10%	10%	10%	10%	10%
	4	10%	10%	10%	10%	10%	10%
	5	20%	20%	20%	20%	20%	20%
	6	5%	5%	5%	5%	5%	5%
	32	5%	5%	5%	5%	5%	5%
	31	5%	5%	5%	5%	5%	5%
79	2	35%	35%	35%	35%	35%	35%
	3	45%	45%	45%	45%	45%	45%
	7	20%	20%	20%	20%	20%	20%
81	1	20%	20%	20%	20%	20%	20%
	3	80%	80%	80%	80%	80%	80%
24	3	80%	80%	80%	80%	80%	80%
	7	20%	20%	20%	20%	20%	20%
44	7	5%	5%	5%	5%	5%	5%
	13	25%	25%	25%	25%	25%	25%
	14	45%	45%	45%	45%	45%	45%
	15	3%	3%	3%	3%	3%	3%
	16	1%	1%	1%	1%	1%	1%
	17	1%	1%	1%	1%	1%	1%
	18	20%	20%	20%	20%	20%	20%
43	19	100%	100%	100%	100%	100%	100%
41	17	20%	20%	20%	20%	20%	20%
	18	80%	80%	80%	80%	80%	80%
40	17	20%	20%	20%	20%	20%	20%
	16	30%	30%	30%	30%	30%	30%
	15	10%	10%	10%	10%	10%	10%
	14	10%	10%	10%	10%	10%	10%
	36	30%	30%	30%	30%	30%	30%
35	36	45%	45%	45%	45%	45%	45%
	47	45%	45%	45%	45%	45%	45%
	35	10%	10%	10%	10%	10%	10%
39	56	55%	55%	55%	55%	55%	55%
	57	35%	35%	35%	35%	35%	35%
	46	10%	10%	10%	10%	10%	10%
38	56	30%	30%	30%	30%	30%	30%
	57	70%	70%	70%	70%	70%	70%

Appendix 4 Summary of allocation of available at-sea samples to group-time periods

Appendix 1 lists available at-sea size samples for the period October 1998 to July 2000. For the Bay of Fundy analysis there were 10 groups of grids, seven time periods in a year (Oct, Nov, Dec, Jan-Mar, April-May, June, July), and two complete fishing seasons (considered as a Fall-Spring fishing season from October to July). Thus, there were a total of 140 possible group-time periods (10 groups x 7 periods x 2 fishing seasons). Due to seasonal closures of the lobster fishery in different LFA s there were actually 108 group-time periods where a fishery was operating, as shown in the table below, where

X - Available at-sea size sample for the group-time period (66 samples, 61% of the required group-time periods)
A – Sample taken from an adjacent month in the same fishing season (24 cases, 22% of the required group-time periods)
O – Sample taken from the same (or an adjacent) month in another fishing season. This was required to fill in the 1998-99 fishing season with data from an expanded 1999-00 sampling program (18 cases, 17% of the required group-time periods)
N – No fishery open

		1998			1999							2000			
LFA	Gp	Oct	Nov	Dec	J-M	A-M	Jun	Jul	Oct	Nov	Dec	J-M	A-M	Jun	Jul
35	1	X	O	O	N	X	X	X	X	X	A	N	X	X	X
35	2	X	O	O	N	A	X	X	X	X	A	N	A	X	X
35	3	X	O	O	N	A	X	X	X	X	A	N	A	X	X
35	4	X	O	O	N	A	X	X	X	X	A	N	A	X	X
36	5	N	O	X	A	A	X	N	N	X	X	A	A	X	N
36	6	N	X	A	A	A	X	N	N	X	A	A	A	X	N
35	7	N	X	O	O	A	X	N	N	X	X	A	A	X	N
38	8	N	O	X	X	X	X	N	N	X	X	X	X	X	N
38	9	N	X	O	O	X	X	N	N	X	X	X	X	X	N
38	10	N	O	O	O	O	X	N	N	A	X	X	X	X	N

Appendix 4. Summary of allocation of available at-sea samples to group-time periods.

Appendix 1 lists available at-sea size samples for the period October 1998 to July 2000. For the Bay of Fundy analysis there were 10 groups of grids, seven time periods in a year (Oct, Nov, Dec, Jan-Mar, April-May, June, July), and two complete fishing seasons (considered as a Fall-Spring fishing season from October to July). Thus, there were a total of 140 possible group-time periods (10 groups x 7 periods x 2 fishing seasons). Due to seasonal closures of the lobster fishery in different LFA's there were actually 108 group-time periods where a fishery was operating, as shown in the table below, where:

X - Available at-sea size sample for the group-time period (66 samples; 61% of the required group-time periods).
A – Sample taken from an adjacent month in the same fishing season (24 cases; 22% of the required group-time periods).
O – Sample taken from the same (or an adjacent) month in another fishing season. This was required to fill in the 1998-99 fishing season with data from an expanded 1999-00 sampling program (18 cases; 17% of the required group-time periods).
N – No fishery open

		1998			1999							2000			
LFA	Gp	Oct	Nov	Dec	J-M	A-M	Jun	Jul	Oct	Nov	Dec	J-M	A-M	Jun	Jul
35	1	X	O	O		X	X	X	X	X	A		X	X	X
35	2	X	O	O		A	X	X	X	X	A		A	X	X
35	3	X	O	O		A	X	X	X	X	A		A	X	X
35	4	X	O	O		A	X	X	X	X	A		A	X	X
36	5		O	X	A	A	X			X	X	A	A	X	
36	6		X	A	A	A	X			X	A	A	A	X	
36	7		X	O	O	A	X			X	X	A	A	X	
38	8		O	X	X	X	X			X	X	X	X	X	
38	9		X	O	O	X	X			X	X	X	X	X	
38	10		O	O	O	O	X			A	X	X	X	X	

Appendix 4 (cont): Summary of sample allocations to fill group-time periods.

Nov 98
- Fill Nov 98Gp1 with Nov99Gp1
- Fill Nov 98Gp2 with Nov99Gp2
- Fill Nov 98Gp3 with Nov99Gp3
- Fill Nov 98Gp4 with Nov99Gp4
- Fill Nov 98Gp5 with Nov99Gp5
- Fill Nov 98Gp8 with Nov99Gp8
- Fill Nov98Gp10 with Dec99Gp10

Dec 98
- Fill Dec 98Gp1 with Nov99Gp1
- Fill Dec 98Gp2 with Nov99Gp2
- Fill Dec 98Gp3 with Nov99Gp3
- Fill Dec 98Gp4 with Nov99Gp4
- Fill Dec 98Gp6 with Nov98Gp6
- Fill Dec 98Gp7with Dec99Gp7
- Fill Dec 98Gp9 with Dec99Gp9
- Fill Dec98Gp10 with Dec99Gp10

J-M99
- Fill J-M99Gp5 with Dec98Gp5
- Fill J-M99Gp6 with Jun99Gp6
- Fill J-M99Gp7 with Dec99Gp7
- Fill J-M99Gp9 with J-M00Gp9
- Fill J-M99Gp10 with J-M00Gp10

A-M99
- Fill A-M99Gp2 with Jun99Gp2
- Fill A-M99Gp3 with Jun99Gp3
- Fill A-M99Gp4 with Jun99Gp4
- Fill A-M99Gp5 with Jun99Gp5
- Fill A-M99Gp6 with Jun99Gp6
- Fill A-M99Gp7 with Jun99Gp7
- Fill A-M99Gp10 with A-M00Gp10

Nov 1999
- Fill Nov99Gp10 with Dec99Gp10

Dec 1999
- Fill Dec99Gp1 with Nov99Gp1
- Fill Dec99Gp2 with Nov99Gp2
- Fill Dec99Gp3 with Nov99Gp3
- Fill Dec99Gp4 with Nov99Gp4
- Fill Dec99Gp6 with Nov99Gp6

J-M 2000
- Fill J-M00Gp5 with Dec99Gp5
- Fill J-M99Gp6 with Jun00Gp6
- Fill J-M99Gp7 with Dec99Gp7

A-M 2000
- Fill A-M00Gp2 with Jun00Gp2
- Fill A-M00Gp3 with Jun00Gp3
- Fill A-M00Gp4 with Jun00Gp4
- Fill A-M00Gp5 with Jun00Gp5
- Fill A-M00Gp6 with Jun00Gp6
- Fill A-M00Gp7 with Jun00Gp7